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Research Article

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Determination of Some Agronomic Traits of Fresh Bean Parents and Hybrids and Their Heritability with Diallel Analysis Method

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ABSTRACT

In this study, three commercial fresh bean cultivars (SF08/03, Ribera and Java) and two pole-type fresh bean lines (Mor Toparlak and Beyaz Toparlak) were hybridized (20 hybrid combinations) in accordance with full-diallel analysis method in 2016. F_1 generations and parents were grown in fully-automated plant breeding greenhouse of Selcuk University in 2017. Measurements, counts, weightings and analyses were formed to determine plant height, pod length, number of pods per plant, number of seed per pod, number of seed per plant, seed yield, hundred-seed weight, protein ratio and protein yields of the parents and hybrids. For investigated traits, diallel analysis method was employed to determine general combining ability (GCA) and specific combining ability (SCA), heterosis and heterobeltiosis values, broad and narrow sense heritability and correlations among the investigated traits of the parents and hybrids. For seed yield, non-additive gene effects and narrow sense heritability values were low. Heterosis and heterobeltiosis values for seed yield of F_1 generation were positive. As to conclude, proper parents and hybrids to be used in further bean breading programs were identified and their agronomic traits and heredities were determined.

1. Introduction

Among the vegetables, beans (*Phaseolus vulgaris* L.) with quire rich nutritional values and great consumptions throughout the world, are significant plants of *Leguminosae* family. They have a significant place in human nutrition (Nadeem et al. 2004). Beans are consumed as fresh, dried and canned foods. Fresh bean is produced almost in all regions of Turkey. It is quite rich in vitamins A, B1, B2 and D. It also neutralize body acids and create base excess in the body. Digestibility of the beans is 84.1%. It was even reported that *phasol* and *phaseolin* in bean pods had similar characteristics with insulin used in diabetes and therefore used to reduce blood sugar levels. Fresh beans supply raw material to vegetable processing industry (Madakbas 2017).

World fresh bean production was 213 651 119 tons from 15 million hectares in 2019. Indonesia with annual production of 881 613 tons corresponding to 41% of world production is the leading fresh bean producer of the world. Indonesia is followed by Turkey (30%) and India (29%) in fresh bean production of the world. On the other hand, with regard to fresh been cultivated lands, India with 1.7 million hectares has the first place and it is followed by Thailand and Indonesia (FAO 2020).

Genotypes with significantly positive general and specific combining ability (GCA and SCA) were reported for plant height, number of pods per plant, number of seed per pod, number of seed per plant and seed yield per plant of fresh bean hybrids (Zimmermann et al. 1985; Singh and Urrea 1994; Oliveira et al. 1997; Rodrigues et al. 1998; Barelli et al. 2000; Bozoglu and Sozen 2007; Ceyhan et al. 2014a;b). The genotypes with a high GCA variance can be used as a basic breeding source in such breeding programs (Oliveira et al., 1997; Oliveira et al., 1997).

It was reported that non-additive genes were effective on plant height, seed yield and hundred-seed weights of beans (Ceyhan et al. 2014b), additive genes were effective on seed yield and harvest index (Zimmermann et al. 1985; Singh and Urrea 1994; Oliveira et al. 1997; Rodrigues et al. 1998; Barelli et al. 2000), a single gene allele was effective on number of ovaries in broad beans (Al-Mukhtar and Coyne 1981), non-additive genes were effective on heredity of pod characteristics and plant height (Rodrigues et al. 1998; Ceyhan et al. 2014b), non-additive genes were also effective on heredity of protein ratio and yield (Ceyhan et al. 2014a).

Previous breeding studies of beans have mostly focused on selection breeding. Therefore, it is now evi-

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dent to focus on hybridizations to improve genetic variations. Such variation to be created through hybridizations and can be used to develop and breed bean varieties and ultimately improve unit area yields and quality, to develop cultivars resistant to pests and diseases and to create gene sources. Plant genetics and environmental factors are the most significant conditions influencing yield and quality of plants. If the genetic structure of the plant is not available for high yield and quality, it will be impossible to improve the yield and quality regardless of quite available environmental conditions. To develop new varieties through breeding works, either high-yield and quality genotypes adaptable to available environmental conditions should be selected or the insufficient aspects of available genotypes should be improved. In present study, hybridizations were performed among 5 fresh bean genotypes with superior agronomic and technological characteristics. The objectives of the present study were set as to investigate genetic structure of F_1 hybrids, to identify proper parents and combinations, to determine heritability, heterosis and heterobeltiosis of investigated traits and finally to identify the hybrids with superior agronomic and technological characteristics and available for machine-agriculture.

2. Materials and Methods

In present study, 3 fresh bean cultivars (Ribera (Romano-type, medium-power plant structure, medium-green fruits, high-yield, able to preserve pod color and freshness for longer periods. Available for fresh consumption, industrial process and machine-harvest), SF08/03 (strong root system, medium earliness. ground-type, cylindrical fruits, elliptic and white seeds) and Java (dwarf-type, early cultivar, smooth pod shape, bright green pod color, stringless pods, recommended to be sown in spring and autumn, available for fresh consumption and canning, suitable for manual and machine-harvest), with already known and superior characteristics and 2 pole-type fresh bean lines (Mor Toparlak (climbing –type, cylindrical pods, light green stringless pods, oval, large and light brown seeds) and Beyaz Toparlak (climbing –type, cylindrical pods, light green stringless pods, oval, large and white seeds) developed by Prof. Dr. CEYHAN through hybridizations and with different characteristics were used as the plant material.

Experiments were conducted in fully-automated breeding greenhouse of Field Crops Department at Selcuk University Agricultural Faculty in 2016. Experiments were initiated with the sowing of 5 fresh bean genotypes at 4 different sowing dates starting from 20th of March. In this way, concurrent flowering of fresh bean genotypes was achieved. For convenient hybridizations, parents were sown over 2m long rows with 1 m row spacing and 20 cm on-row plant spacing. Hybridizations were performed in accordance with Ceyhan et al. (2014b). At least 23 seeds were obtained from each one of 20 hybrid combinations.

Hybridizations were conducted with 9 full-diallel (reciprocal) parents in accordance with 5x5 equation and 20 hybrid combinations were obtained. Of the hybrid seeds, 15 and parents were also grown under greenhouse conditions. Greenhouse experiments were conducted in "Randomized Blocks Design" with three replications over 1 m long plots. Experiments were set up at "Fully Automated Plant Breeding Greenhouse of Selcuk University" on 15 April 2017. Harvest was performed in August. To meet the nutritional needs of the hybrids and parents, a uniform 15 kg DAP (Diammonium Phosphate) was applied to all plots. Manual and machine weed control was practiced and 5 irrigations were performed through drip irrigation. Throughout out plant growth period in fully-automated breeding greenhouse, day temperature was set at 25 ºC, night temperature was set at 18 ºC, relative humidity was set at 50-55% and wind speed was set at 5 km/h.

Measurements and counts on investigated parameters were performed on parents and hybrids of 5 plants of each plot. Plant height, pod length, number of pods per plant, number of seed per pod, number of seed per plant, seed yield, hundred-seed weight, protein ratio and protein yield were investigated in this study (Ceyhan et al. 2014a;b).

The measurements and observations made on F_1 plants were initially subjected to variance analysis in accordance with "Randomized Blocks Design". Diallel analysis was performed for traits between with there are 1% and at least 5% significant variance. This analysis and calculations were conducted with TARPOP-GEN software.

The method specified by (Griffing 1956) was taken into consideration and Model-I and Metot-1 were employed in diallel hybrids. This method covers parents and hybrids including reciprocals. Broad sense heritability of investigated traits was determined with variance components method. Narrow sense heritability was expressed as the ratio of additive genetic variance to phenotypic variance (Falconer 1980). Percent heterosis values were calculated in accordance with the principles specified in Fonseca and Patterson (Fonseca and Patterson 1968).

3. Results and Discussion

Mean squares of initial variance analysis and combining ability variance analysis for investigated traits are provided in full diallel hybrid set in Table 1.

In full diallel variance analysis for investigated traits, mean squares of hybrids were found to be significant for all traits. Genotypes had significant variation at 1% level for all traits (Table 1). Combining ability variance analysis in full-diallel hybrid set revealed significant differences in GCA values for all traits except for number of seeds per pod. On the other hand, significant differences were observed in SCA values for all traits. With regard to variations in reciprocal effect, differences in all traits were found to be significant (Table 1).

Table 1
Mean squares of initial variance analysis and combining ability variance analysis for investigated traits in full-diallel hybrid set

Source of Variation	SD	Plant Height	Pod Length	Number of Pods per Plant	Number of Seeds per Pod	Number of Seeds per Plant
Blocks	2	205.013	2.736	3.040	0.120	18.840
Genotypes	24	6152.802**	8.884**	53.667**	1.919**	1302.056**
Error	48	487.861	2.456	9.373	0.676	159.604
GCA	4	8168.603**	4.681**	26.394**	0.192	444.839**
SCA	10	1084.378**	3.600**	21.326**	0.930**	571.920**
Reciprocal Effect	10	570.422**	1.635	11.050**	0.528*	291.789**
Error	48	162.620	0.819	3.124	0.225	53.2013
Source of Variation	SD	Seed Yield	Hundred Seed Weight	Protein Ration	Protein Yield	
Blocks	2	52.239	10.720	0.234	4.184	
Genotypes	24	306.678**	463.333**	19.017**	17.453**	
Error	48	37.905	17.803	0.228	2.446	
GCA	4	155.144**	225.322**	27.983**	2.5392*	
SCA	10	104.539**	179.6933**	2.483**	8.226**	
Reciprocal Effect	10	78.746**	100.844**	1.537**	4.720**	
Error	48	12.635	5.934	0.076	0.815	

* : significant at 5% level , ** : significant at 1% level

3.1. Plant heights:

Among the morphological characteristics, plant height plays a significant role in yield levels, therefore it is considered as an important yield factor (Ceyhan 2004; Sozen et al., 2014). Recent breeding studies on fresh beans focused on development of dwarf cultivars available for machine harvest. Plant heights of F_1 generation varied between 32.67 cm (SF 08/03 x Ribera) and 166.33 cm (Mor Toparlak x SF 08/03) (Table 2). Previous researchers also reported similar findings for plant heights of fresh bean cultivars (Ceyhan et al. 2014b; Ceyhan 2004; Genchev 1995; Ulker and Ceyhan 2008).

With regard to plant height, σ²GCA was lower than σ²SCA and $(H/D)^{1/2}$ ratio was greater than 1 (Table 2). Such findings revealed that non-additive gene effects and dominant gene effects were effective on heredity of this trait. Ceyhan et al. (2014b) also reported the effects of non-additive genes and dominant gene effects on heritability of plant height of fresh beans.

With regard to parent GCA for plant height, while Mor Toparlak and Beyaz Toparlak had significant positive ($p < 0.01$) GCA, SF 08/03 ($p<0.05$), Ribera ($p<0.01$) and Java ($p<0.01$) had significant negative GCA (Table 3). Therefore, Mor Toparlak and Beyaz Toparlak cultivars with significant positive GCA were identified as the parents to be used in hybridization studies to increase plant heights. On the other hand, SF 08/03, Ribera and Java cultivars with significant negative GCA could reliably be used in breeding for short or medium-height cultivars.

Considering the SCA of the hybrids in F_1 generation, it was observed that "Ribera x Java", "SF 08/03 x Mor Toparlak", "SF 08/03 x Beyaz Toparlak" ($p<0.05$) hybrids had significant positive SCA and these combinations were identified as the genotypes with a breeding potential for long plant heights (Table 3). With regard to reciprocal effects of hybrids in F_1 generation, it was observed that "Mor Toparlak x SF 08/03" and "Beyaz Toparlak x Ribera" ($p<0.05$) hybrids had significant positive reciprocal effects. Such findings revealed that cytoplasm or cytoplasm x nucleus interactions created significant variations in this trait.

Very plant heights are not ideal because of lodging problem. Therefore, medium-height cultivars are preferred in bean culture. In this sense, the parents with significant negative GCA values could be used to shorten plant heights and the parents with significant positive GCA values could be used to increase plant heights. On the other hand, the hybrids with significant positive SCA values could be used for greater plant heights and the ones with significant negative SCA values could be used for shorter or medium plant heights. Previous researchers working on plant height also reported significant GCA and SCA values for various parents and hybrids (Rodrigues et al. 1998; Barelli et al. 2000; Ceyhan et al. 2014b; Arunga et al. 2010).

Mean heterosis value in F_1 generation was 33.56%. Except for 5 hybrids, the rest had positive heterosis values. Present heterosis values varied between -32.16% (Mor Toparlak x Beyaz Toparlak) and 137.99% (Java x Ribera) (Table 4). Rodrigues et al. (1998), Barelli et al. (2000), Ceyhan et al. (2014b) and Arunga et al. (2010) also investigated heterosis values for plant height and reported either greater or lower heterosis values for this trait.

Broad sense and narrow sense heritability values for plant height in F_1 generation was identified as 0.93 and 0.47 respectively (Table 2). High broad sense heritability for plant height and medium narrow sense heritability values indicated that this trait had high environmental variation and genotype variation was also effective. Non-additive gene effects were also significant in F_1 generation. These findings also indicated that selection for plant height could be performed at later generations.

Table 2
Mean values for investigated traits in full-diallel hybrid set

Parents	Plant Height	Pod Length	Number of Pods per Palnt	Number of Seeds per Pod	Number of Seeds per Plant
SF 08/03	40.00	15.43	10.67	4.00	42.33
Ribera	29.00	15.70	10.67	4.33	42.67
Java	30.67	16.17	10.33	3.33	33.00
Mor Toparlak (MT)	167.67	10.83	16.67	4.67	77.00
Beyaz Toparlak (BT)	136.00	13.17	16.33	4.67	76.00
F_1 Hybrids					
SF 08/03 X Ribera	32.67	13.00	14.67	4.67	67.33
SF 08/03 X Java	41.33	13.33	14.33	7.00	100.00
SF 08/03 X MT	123.67	12.87	27.00	4.33	116.67
SF 08/03 X BT	149.33	13.53	16.33	3.67	58.00
Ribera X SF 08/03	60.67	11.77	19.00	4.67	86.00
Ribera X Java	48.00	11.67	17.33	5.67	97.67
Ribera X MT	104.00	10.23	26.67	3.67	97.00
Ribera X BT	59.67	9.50	16.67	4.33	71.67
Java X SF 08/03	59.33	11.67	15.00	5.33	80.00
Java X Ribera	71.00	11.30	11.67	3.33	39.67
Java X MT	118.00	11.43	15.33	5.00	76.67
Java X BT	115.33	13.17	16.67	3.67	59.33
MT X SF 08/03	166.33	10.67	23.33	4.00	93.33
MT X Ribera	115.00	11.00	14.67	4.67	69.00
MT X Java	121.67	11.17	16.33	5.33	86.67
MT X BT	103.00	11.67	14.33	4.67	65.33
BT X SF 08/03	152.67	13.27	16.33	4.33	69.67
BT X Ribera	137.67	13.20	17.00	4.67	79.33
BT X Java	83.00	10.17	13.33	4.00	53.33
BT X MT	129.00	11.67	14.33	4.00	57.33
GCA	533.73	0.26	1.55	0.00	26.11
SCA	921.76	2.78	18.20	0.71	518.72
Reciprocal	135.93	0.27	2.64	0.10	79.53
σ^2GKK/ σ^2ÖKK	0.58	0.09	0.09	0.01	0.05
$H/D^{1/2}$	2125.16	3.57	23.95	0.80	650.47
H^2	0.93	0.80	0.88	0.78	0.93
h^2	0.47	0.12	0.11	0.01	0.07

GCA: General Combining Ability; SCA: Specific Combining Ability; $H/D^{1/2}$: Mean Degree of Dominance; H^2: Broad Sense Heritability; h^2: Narrow Sense

*3.2. Pod lengths***:**

In breeding of high-yield bean cultivars, selection of plants with longer pod lengths is a significant issue. With increasing pod lengths, number of seeds per pod and pod yield will increase, thus the yield will ultimately also increase (Ulker and Ceyhan 2008). Parent pod lengths varied between 10.83 cm (Mor Toparlak) and 16.17 cm (Java), F_1 generation pod lengths varied between 9.50 cm (Ribera x Beyaz Toparlak) and 13.53 cm (SF 08/03 x Beyaz Toparlak) (Table 2). Similar findings were also reported by previous researchers (Zimmermann et al. 1985; Ceyhan et al. 2014b; Genchev 1995; Ulker and Ceyhan 2008).

Greater σ^2SCA than σ^2GCA for pod length indicated that non-additive gene effect was effective in heredity of this trait (Table 3). Similar findings were also reported by Ceyhan et al. (2014b). Significant non-additive gene effect indicated that selections for this trait could be initiated at later generations.

With regard to GCA for pod length, it was observed that SF 08/03 cultivar had a significant positive value ($p<0.05$) and Mor Toparlak cultivar had a significant negative value ($p<0.05$) (Table 3). Therefore, SF 08/03 cultivar with a significant positive GCA was identified as a proper parent to be used in breeding studies to increase pod lengths.

Considering the SCA of F_1 generation, it was observed that “Ribera x Java” hybrid had a significant negative SCA ($p<0.05$) and the rest did not have significant SCA values (Table 3). With regard to reciprocal effects of hybrids in F_1 generation, while “Beyaz Toparlak x Ribera” ($p<0.05$) had significant positive effects, “Beyaz Toparlak x SF 08/03” and “Beyaz Toparlak x Java” ($p<0.05$) had significant negative reciprocal effects (Table 3). Ceyhan et al. (2014b) and Arunga et al. (2010) also reported significant GCA and SCA values for pod length.

Table 3
Genetic components for investigated traits in full-diallel hybrid set

Parents	Plant Height	Pod Length	Number of Pods per Plant	Number of Seeds per Pod	Number of Seeds per Plant
SF 08/03	-9.187*	0.794*	0.533	0.120	3.767
Ribera	-27.120**	0.004	-0.300	-0.047	-2.500
Java	-23.887**	0.321	-2.133*	0.120	-5.867*
Mor Toparlak (MT)	35.813**	-1.066*	2.333*	0.020	9.800*
Beyaz Toparlak (BT)	24.380**	-0.053	-0.433	-0.213	-5.200*
F_1 Hybrids					
SF 08/03 X Ribera	-12.813	-0.717	0.400	0.113	3.600
SF 08/03 X Java	-12.380	-0.917	0.067	1.447**	20.300*
SF 08/03 X MT	22.587*	-0.264	6.100**	-0.453	19.633*
SF 08/03 X BT	40.020*	0.356	0.033	-0.387	-6.533
Ribera X SF 08/03	14.000	-0.617	2.167	0.000	9.333
Ribera X Java	14.720*	-1.144*	0.733	-0.053	5.233
Ribera X MT	5.020	-0.624	2.433*	-0.287	3.900
Ribera X BT	5.620	-0.904	1.367	0.280	11.400*
Java X SF 08/03	9.000	-0.833	0.333	-0.833*	-10.000
Java X Ribera	11.500	-0.183	-2.833*	-1.167*	-29.000**
Java X MT	12.120	-0.257	-0.567	0.547*	5.933
Java X BT	2.887	-0.904	1.367	-0.553*	-4.400
MT X SF 08/03	21.333*	-1.100	-1.833	-0.167	-11.667*
MT X Ribera	5.500	0.383	-6.000*	0.500	-14.000*
MT X Java	1.833	-0.133	0.500	0.167	5.000
MT X BT	-39.980*	0.483	-3.767*	0.047	-15.067
BT X SF 08/03	1.667	-0.133*	0.000	0.333	5.833
BT X Ribera	39.000*	1.850*	0.167	0.167	3.833
BT X Java	-16.167	-1.500*	-1.667	0.167	-3.000
BT X MT	13.000	0.000	0.000	-0.333	-4.000
G_i	13.010	0.065	0.250	0.018	4.256
S_{ij}	55.291	0.278	1.062	0.077	18.088
R_{ij}	81.310	0.409	1.562	0.113	26.601

G_i : GCA, S_{ij}: SCA; R_{ij}: Reciprocal effect, ** : significant at 1% level; * : significant at 5% level

Heterosis values for pod length varied between -34.18% (Ribera x Beyaz Toparlak) and -2.03% (SF 08/03 x Mor Toparlak). Only four hybrids, the rest had significant heterosis values for this trait (Table 4).

Broad sense and narrow sense heritability values for pod length in F_1 generation was respectively identified as 0.80 and 0.12 (Table 2). Low narrow sense heritability in F_1 generation indicated that environment had greater effects than the genetics for this trait. Since number of seeds per pod and thus the yield increase with increasing pod lengths and because of significant non-additive gene effect and weak hybrid power in present generation, a selection for pod length (together with seed yield) could be initiated at later generations.

3.3. Number of pods per plant:

Besides environmental conditions, high seed yield in beans also largely depend on yield components. Number of pods per plant is among the most significant yield components effecting yields (Ulker and Ceyhan, 2008). Number of pods per plant in parents varied between 10.33 pods/plant (Java) and 16.67 pods/plant (Mor Toparlak), number of pods per plant in F_1 generation varied between 11.67 pods/plant (Java x Ribera) and 26.67 pods/plant (Ribera x Mor Toparlak) (Table 2). Similar findings were also reported by Ceyhan et al. (2014b), Ülker and Ceyhan (2008), Varankaya and Ceyhan (2012) and Sozen and Bozoglu (2016).

Table 4
Heterosis (%) values for investigated traits in full-diallel hybrid set

F_1 Hybrids	Plant Height	Pod Length	Number of Pods	Number of Seeds per Pod	Number of Seeds per Plant
SF 08/03 X Ribera	-5.31	-16.49**	37.50**	12.00**	58.43*
SF 08/03 X Java	16.98	-15.61**	36.51**	90.91**	165.49**
SF 08/03 X MT	19.10	-2.03	97.56**	0.00	95.53**
SF 08/03 X BT	69.70	-5.36**	20.99**	-15.38**	-1.97
Ribera X SF 08/03	75.85	-24.41**	78.13**	12.00**	102.35**
Ribera X Java	60.89	-26.78**	65.08**	47.83**	158.15**
Ribera X MT	5.76	-22.86**	95.12**	-18.52**	62.12*
Ribera X BT	-27.68	-34.18**	23.46**	-3.70*	20.79
Java X SF 08/03	67.92	-26.16**	42.86**	45.45**	112.39**
Java X Ribera	137.99	-29.08**	11.11*	-13.04**	4.85
Java X MT	18.99	-15.31**	13.58**	25.00**	39.39
Java X BT	38.40	-10.23**	25.00**	-8.33**	8.87
MT X SF 08/03	60.19	-18.78**	70.73**	-7.69**	56.42*
MT X Ribera	16.95	-17.09**	7.32	3.70*	15.32
MT X Java	22.69	-17.28**	20.99**	33.33**	57.58*
MT X BT	-32.16	-2.78	-13.13**	0.00	-14.60
BT X SF 08/03	73.48	-7.23**	20.99**	0.00	17.75
BT X Ribera	66.87	-8.55**	25.93**	3.70*	33.71
BT X Java	-0.40	-30.68**	0.00	0.00	-2.14
BT X MT	-15.04	-2.78	-13.13**	-14.29**	-25.05
Mean	33.56	-16.68	33.33	9.65	48.27

** : significant at 1% level; * : significant at 5% level

Lower GCA variance than SCA variance for this trait indicated that non-additive gene effect was effective in heredity of this trait (Table 3). It was also reported in previous studies that number of ovaries in pod in beans was under the additive effect of a single gene allele (Al-Mukhtar and Coyne 1981), number of pods was under the effect of non-additive genes (Rodrigues et al. 1998; Ceyhan et al. 2014b) and additive genes (Barelli et al. 2000; Da Silva et al. 2004).

With regard to GCA values of the parents, it was observed that while Mor Toparlak ($p<0.05$) cultivar had significant positive effect, Java cultivar had significant negative effect ($p<0.05$) (Table 3). Therefore, Mor Toparlak cultivar with a significant positive GCA value can be recommended as a parent in further breeding studies to increase number of pods. There is a positive correlation between number of pods per plant and seed yield (Ceyhan 2004; Ulker and Ceyhan, 2008).

Considering the SCA of the hybrids in F_1 generation, it was observed that while “SF 08/03 x Mor Toparlak” ($p<0.01$) and “Ribera x Mor Toparlak” ($p<0.05$) combinations had significant positive SCA effect, “Mor Toparlak x Beyaz Toparlak” ($p<0.05$) combination had significant negative SCA effect. The others did not have significant SCA effects (Table 3).

Seed yield is the most significant yield component in edible legumes. Number of pods per plant contribute significantly in seed yield. Seed yields automatically increases with increasing number of pods per plant (Ceyhan et al. 2014b; Ceyhan 2004; Ulker and Ceyhan 2008; Varankaya and Ceyhan 2012). Therefore, Mor Toparlak cultivar with significant positive GCA for number of pods per plant could be recommended as a proper parent in breeding studies to be carried for high number of pods per plant. Similarly, “SF 08/03 x Mor Toparlak” ($p<0.01$) and “Ribera x Mor Toparlak” ($p<0.05$) hybrids with significant positive SCA could be used as proper combinations to improve number of pods per plant. Similar significant GCA and SCA values for number of pods per plant of the parents and hybrids were also reported by previous researchers (Rodrigues et al. 1998; Barelli et al. 2000; Ceyhan et al. 2014b; Al-Mukhtar and Coyne 1981; Arunga et al. 2010).

Heterosis values in F_1 generation varied between -13.13% (Mor Toparlak x Beyaz Toparlak x Beyaz and Toparlak x Mor Toparlak) and 97.56% (SF 08/03 x Mor Toparlak) with a mean value of 33.33%. Except for two hybrids, all the others had significant heterosis values (Table 4).

Seed yield in beans is a quantitative characteristic depending on several factors. Yield-designating factors on the other hand largely depend on genotypic and environmental conditions. Desired yield levels could be achieved only with the culture of cultivars under optimum conditions. Number of seeds per pod is also greatly influenced by environmental conditions. Large range of heterosis and heterobeltiosis values of the hybrids indicated that this treat greatly influenced by environmental conditions. High heterosis value of this generation indicated that these hybrid generations could be used as a significant source for greater number of pods per plant. Barelli et al. (2000), Ceyhan et al. (2014b) and Arunga et al. (2010) also investigated heterosis and heterobeltiosis values for number of pods per plant and reported both significant positive and negative heterosis and heterobeltiosis values.

Broad and narrow sense heritability in F_1 generation was respectively identified as 0.88 and 0.11 (Table 2). High broad sense heritability and low or medium narrow sense heritability in F_1 generation indicated that number of pods per plant was greatly influenced by environmental factors. Because of significant non-additive gene effects in present generation, selections should be initiated after 3-4 generations.

3.4. Number of seeds per pod.

Number of seeds per pod is a significant yield component in developing high-yield cultivars (Ceyhan 2004). There is a positive relationship between seed yield and number of seeds per pod. Seed yields can be increased through increasing number of seeds per pod. Number of seeds per pod of parents varied between 3.33 seeds/pod (Java) and 4.67 seeds/pod (Mor Toparlak and Beyaz Toparlak) and number of seeds per pod in F_1 generation varied between 3.33 seed/pod (Java x Ribera) and 7.00 seeds/pod (SF 08/03 x Java) (Table 2). Present findings comply with the results of Ceyhan et al. (2014b), Ülker and Ceyhan (2008) and Varankaya and Ceyhan (2012).

Quite greater SCA variance than GCA variance for number of seeds per pod indicated that non-additive gene effect was effective in heredity of this trait (Table 3). Al-Mukhtar and Coyne (1981) indicated that number of ovaries per pod in beans was under the effect of non-additive effect of single gene allele. Ceyhan et al. (2014b) also indicated non-additive gene effects for number of seeds per pod.

With regard to GCA, while Java, SF 08/03 and Mor Toparlak cultivars had positive effects, Beyaz Toparlak and Ribera cultivars had negative values (Table 3). Therefore, Java, SF 08/03 and Mor Toparlak cultivars with positive GCA values were identified as the parents to be used in breeding studies to increase number of seeds per pod in beans (Ceyhan 2004; Ulker and Ceyhan 2008).

Considering the SCA effects of hybrids in F_1 generation, it was observed that while “SF 08/03 x Java” ($p<0.01$) and “Java x Mor Toparlak” ($p<0.05$) combinations had significant positive effects, “Java x Beyaz Toparlak” ($p<0.05$) combination had significant negative SCA effect. Except for these hybrids, the rest did not have significant SCA effect (Table 3).

Since “SF 08/03 x Java” ($p<0.01$) and “Java x Mor Toparlak” ($p<0.05$) hybrids had highly significant positive SCA effects, they were considered as proper combinations to be used in increasing number of seeds per pod. Significant GCA and SCA effects were also reported in previous studies for number of seeds per pod (Rodrigues et al. 1998; Barelli et al. 2000; Ceyhan et al. 2014b; Al-Mukhtar and Coyne 1981; Arunga et al. 2010; Ceyhan and Şimşek 2021).

Heterosis values in F_1 generations varied between -18.52% (Ribera x Mor Toparlak) and 90.91% (SF 08/03 x Java) with a mean value of 9.65%. Except for four hybrids, the rest had significant heterosis values for this trait (Table 4). Ceyhan et al. (2014b) investigated heterosis and heterobeltiosis values for number of seeds per pod and reported both positive and negative heterosis and heterobeltiosis values.

Broad and narrow sense heritability values for number of seeds per pod in F_1 generation was respectively identified as 0.78 and 0.01 (Table 2). High broad sense heritability and low narrow sense heritability in F_1 generation indicated that number of kernels per pod was greatly influenced by environmental factors. Because of significant non-additive gene effects in present generation, selections should be initiated after 3-4 generations.

3.5. Number of seeds per plant.

Several researchers indicated significant effects of number of seeds per plant on seed yield (Ceyhan et al., 2014b; Ulker and Ceyhan, 2008; Varankaya and Ceyhan, 2012). Number of seeds per plant of the parents varied between 33.00 seed/plant (Java) and 77.00 seeds/plant (Mor Toparlak) and number of seeds per plant in F_1 generation varied between 39.67 seeds/plant (Java x Ribera) and 116.67 seeds/plant (SF 08/03 x Mor Toparlak) (Table 2). Similar findings were also reported by Ceyhan et al. (2014b), Ülker and Ceyhan (2008), Varankaya and Ceyhan (2012), Sozen and Karadavut (2017) and Tamüksek and Ceyhan (2020).

For number of seeds per plant, GCA variance was smaller than SCA variance. Such a case indicated that non-additive gene effect was effective on heredity of this trait (Table 3). Barelli et al. (2000) indicated that additive and non-additive genes had equal effects on heredity of number of seeds per pod in beans. Ceyhan et al. (2014b), Tamüksek and Ceyhan (2020) and Ceyhan and Şimşek (2021) indicated significant effects of non-additive genes on heredity of number of seeds per pod in beans.

With regard to GCA of the parents, while Mor Toparlak ($p<0.05$) cultivar had significant positive effects, Java and Beyaz Toparlak cultivars had significant negative values ($p<0.05$) (Table 3). Therefore, Mor Toparlak ($p<0.05$) with a highly significant positive GCA was identified as the parent to be used in increasing number of kernels per plant in beans.

Considering the SCA of the hybrids in F_1 generation, it was observed that “SF 08/03 x Java”, “SF 08/03 x Mor Toparlak” and “Ribera x Beyaz Toparlak” combinations had significantly positive ($p<0.05$) SCA effects. Except for these hybrids, the others did not have significant SCA effects (Table 3). Since “SF 08/03 x Java”, “SF 08/03 x Mor Toparlak” and “Ribera x Beyaz Toparlak” hybrids in F_1 generation had highly significant positive SCA effects, they were identified as proper combinations to increase number of seeds per plant.

Heterosis values in F_1 generation varied between -25.05% (Beyaz Toparlak x Mor Toparlak) and 165.49% (SF 08/03 x Java). With regard to this trait, only nine hybrids had significant heterosis values (Table 4).

Broad and narrow sense heritability of number of seeds per plant in F_1 generation was respectively identified as 0.93 and 0.07 (Table 2). High broad sense heritability and low narrow sense heritability in F_1 generation indicated that number of seeds per plant was also greatly influenced by environmental factors. Because of significant non-additive gene effects in present generation, it is better to initiate selections after 3-4 generations.

3.6. Seed yield:

It is quite difficult to identify high-yield genotypes of self-pollinating plants like beans in early generations. Although single seed yields are used to determine the seed yields of the genotype in breeding programs, great impacts of environmental conditions on this trait make precise assessments difficult. Mean seed yields of the parents varied between 19.34 g/plant (Java) and 45.09 g/plant (Beyaz Toparlak) and mean seed yields in F_1 generation varied between 20.72 g/plant (Java x Ribera) and 56.92 g/plant (Beyaz Toparlak x Ribera) (Table 5). Present findings comply with the results of Ceyhan et al. (2014b), Ülker and Ceyhan (2008), Varankaya and Ceyhan (2012) and Sozen et al. (2018).

Greater SCA variance than GCA variance for seed yield indicated that non-additive gene effect was effective on heredity of this trait. Similarly, a $(H/D)^{1/2}$ ratio of greater than 1 indicated superior dominance and supported that finding (Table 5). Present findings revealed that heredity of seed yield of beans was not a simple characteristic. Some previous researchers indicated that additive genes were effective in heredity of seed yield in beans (Zimmermann et al., 1985; Singh and Urrea, 1994; Oliveira et al., 1997; Rodrigues et al., 1998) and some others indicated that non-additive genes were effective (Barelli et al. 2000 and Ceyhan et al. 2014b; Tamüksek and Ceyhan 2020; Ceyhan and Şimşek 2021).

If the heredity of seed yield is dominated by additive gene effect, then selections can be initiated at early generations and superior genotypes can be identified at greater success. However, dominancy was effective in heredity of seed yield in beans instead of additive genes and such a case then reduces the rate of success in selections for this trait at early generations. In such cases, success is largely depending on type of effective epistasis. Selections for seed yield should be performed at later generations and transfer of superior genotypes to further generations should be provided.

With regard to GCA values in F_1 generation, it was observed that Mor Toparlak and Beyaz Toparlak cultivars had significant positive values ($p<0.05$) and SF 08/03, Ribera and Java cultivars had significant negative values ($p<0.05$) (Table 6). Therefore, Mor Toparlak and Beyaz Toparlak cultivars with significant positive GCA value were identified as promising parents to be used in further hybridizations for seed yield.

Considering the SCA values of hybrids in F_1 generation, it was observed that “SF 08/03 x Mor Toparlak”, “Java x Mor Toparlak” and “Ribera x Beyaz Toparlak” ($p<0.05$) had significant positive SCA effect. These hybrid combinations with quite high significant SCA values could be considered as genotypes with a breeding potential for seed yields in further generations (Table 6). Previous researchers also investigated GCA and SCA effects on seed yield of beans and reported significant GCA and SCA values for parents and hybrids (Zimmermann et al. 1985; Singh and Urrea 1994; Oliveira et al. 1997; Rodrigues et al. 1998; Barelli et al., 2000; Arunga et al., 2010, Ceyhan et al. 2014b; Tamüksek and Ceyhan 2020).

Heterosis values for seed yield varied between -27.11% (Beyaz Toparlak x Mor Toparlak) and 105.99% (Ribera x Java) with a mean value of 31.82% (Table 7). Except for two hybrids, the rest exhibited significant positive heterosis. These hybrids were then identified as proper hybrids for further generations (Ceyhan et al. 2014b; Tamüksek and Ceyhan 2020).

Broad and narrow sense heritability for seed yield in F_1 generation was respectively identified as 0.90 and 0.13 (Table 5). High broad sense heritability and low narrow sense heritability for seed yield indicated that this trait was greatly influenced by environmental factors. Again low narrow sense heritability and non-additive gene effects on heredity of this trait reduce the rate of success in selections for seed yield in early generations. Rate of success can be improved through selecting the genotypes with quite high heredity for seed yield instead of selecting high-yield genotypes in early generations.

3.7. Hundred seed weight.

As it was in all plants, hundred seed weight is a significant yield component with direct impacts on yields. Hundred seed weights of the parents varied between 55.67 g (Ribera and Mor Toparlak) and 62.67 g (Beyaz Toparlak) and hundred seed weight of hybrids in F_1 generation varied between 29.33 g (Java x SF 08/03 and SF 08/03 x Java) and 77.33 g (Beyaz Toparlak x Java) (Table 5). Similar findings were also reported by previous researchers (Ceyhan et al. 2014b; Ceyhan 2004; Ulker and Ceyhan 2008; Arunga et al. 2010; Tamüksek and Ceyhan 2020; Ceyhan and Şimşek 2021).

Greater GCA variance than SCA variance indicated that non-additive gene effect was effective on heredity of hundred seed weight (Table 5). Ceyhan et al. (2014b) also indicated non-additive gene effects on heredity of hundred seed weight in beans.

Table 5
Mean values for investigated traits in full-diallel hybrid set

Parents	Seed Yield	Hundred Seed Weight	Protein Ration	Protein Yield
SF 08/03	23.46	57.33	25.71	6.01
Ribera	22.73	55.67	23.57	5.36
Java	19.34	59.33	26.80	5.24
Mor Toparlak (MT)	39.56	55.67	20.01	7.93
Beyaz Toparlak (BT)	45.09	62.67	21.99	9.92
F_1 Hybrids				
SF 08/03 X Ribera	34.40	53.33	28.90	9.95
SF 08/03 X Java	31.19	29.33	28.13	8.76
SF 08/03 X MT	54.94	58.67	26.06	14.31
SF 08/03 X BT	39.47	68.33	28.11	11.07
Ribera X SF 08/03	28.31	36.33	28.42	8.05
Ribera X Java	43.33	49.33	25.91	11.21
Ribera X MT	43.00	47.33	23.72	10.20
Ribera X BT	27.93	37.67	25.49	7.12
Java X SF 08/03	26.87	29.33	28.33	7.62
Java X Ribera	20.72	45.67	28.60	5.92
Java X MT	45.75	58.00	24.66	11.31
Java X BT	38.75	67.33	23.57	9.14
MT X SF 08/03	44.22	54.67	23.74	10.50
MT X Ribera	40.09	55.67	24.04	9.64
MT X Java	45.23	60.00	24.23	10.96
MT X BT	35.08	54.00	21.28	7.46
BT X SF 08/03	42.63	66.33	24.16	10.27
BT X Ribera	56.92	76.67	24.15	13.74
BT X Java	42.80	77.33	23.85	10.21
BT X MT	30.85	54.00	20.95	6.46
GCA	9.50	14.63	1.86	0.11
SCA	91.90	173.76	2.41	7.41
Reciprocal	22.04	31.64	0.49	1.30
σ^2GKK/ σ^2ÖKK	0.10	0.08	0.77	0.02
$H/D^{1/2}$	132.94	234.65	6.62	8.94
H^2	0.90	0.97	0.99	0.90
h^2	0.13	0.12	0.56	0.02

GCA: General Combining Ability; SCA: Specific Combining Ability; $H/D^{1/2}$: Mean Degree of Dominance; H^2: Broad Sense Heritability; h^2: Narrow Sense

Considering the GCA of the parents for hundred seed weight, it was observed that while Beyaz Toparlak cultivar had a significant positive value ($p<0.01$), SF 08/03 and Ribera cultivars had a significant negative ($p<0.01$) value (Table 6). Beyaz Toparlak with significant positive GCA value was considered as a proper parent to be used in further breeding studies to increase hundred seed weight of the beans.

With regard to SCA of hybrids in F_1 generation, it was observed that “SF 08/03 x Mor Toparlak”, “Java x Mor Toparlak”, “SF 08/03 x Beyaz Toparlak”, “Java x Beyaz Toparlak” hybrids with significant positive SCA value could be used as promising genotypes in further breeding studies to be carried out to increase hundred seed weights. On the other hand, “SF 08/03 x Ribera”, “SF 08/03 x Java” and “Mor Toparlak x Beyaz Toparlak” hybrids had significant negative SCA values (Table 6). Barelli et al. (2000), Ceyhan et al. (2014b), Tamüksek and Ceyhan (2020) and Ceyhan and Şimşek (2021) also reported genotypes with significant positive GCA and SCA values.

Heterosis values in F_1 generation varied between -49.71% (SF 08/03 x Java and Java x SF 08/03) and 29.58% (Beyaz Toparlak x Ribera). Except for six hybrids, all the rest had significant heterosis values (Table 7). Negative mean heterosis value of F_1 generations indicated that non-additive gene effects were effective on this trait. Such a case was probably resulted from the above mention reason or reverse dominance effect.

Broad and narrow sense heritability for hundred seed weight in F_1 generation was respectively identified as 0.97 and 0.12 (Table 5). Lower narrow sense heritability value indicated that hundred seed weights were greatly influenced by environmental factors. Considering the significant effects of non-additive genes on heredity of hundred seed weight, it was recommended that selections should be initiated in later generations.

Table 6
Genetic components for investigated traits in full-diallel hybrid set

Parents	Seed Yield	Hundred Seed Weight	Protein Ration	Protein Yield
SF 08/03	-2.012*	-3.700**	1.751**	0.121
Ribera	-2.891*	-3.467**	0.662**	-0.479
Java	-3.575*	-1.300	1.113**	-0.573*
Mor Toparlak (MT)	4.923*	0.567	-2.105**	0.535*
Beyaz Toparlak (BT)	3.555*	7.900**	-1.421**	0.396
F_1 Hybrids				
SF 08/03 X Ribera	-0.646	-2.800*	1.269**	0.222
SF 08/03 X Java	-2.292	-20.467**	0.391*	-0.494
SF 08/03 X MT	9.764*	5.000*	0.279	2.616**
SF 08/03 X BT	2.600	8.333**	0.827**	1.019
Ribera X SF 08/03	-3.043	-8.500**	-0.242	-0.951
Ribera X Java	1.582	-2.533	0.504*	0.486
Ribera X MT	2.607	-0.400	0.349*	0.731
Ribera X BT	4.855*	-2.067	0.605*	1.377*
Java X SF 08/03	-2.160	0.000	0.098	-0.573
Java X Ribera	-11.305*	-1.833	1.342**	-2.645*
Java X MT	7.239*	4.933*	0.459*	2.037*
Java X BT	3.886	10.933**	-0.956**	0.717
MT X SF 08/03	-5.360*	-2.000	-1.158**	-1.906*
MT X Ribera	-1.455	4.167**	0.158	-0.280
MT X Java	-0.258	1.000	-0.213	-0.172
MT X BT	-12.418**	-9.267**	-0.334*	-3.106**
BT X SF 08/03	1.582	-1.000	-1.977**	-0.398
BT X Ribera	14.492**	19.500**	-0.672*	3.308**
BT X Java	2.025	5.000*	0.138	0.534
BT X MT	-2.115	0.000	-0.163	-0.499
G_i	1.011	0.475	0.006	0.065
S_{ij}	4.296	2.018	0.026	0.277
R_{ij}	6.317	2.967	0.038	0.408

G_i : GCA, S_{ij}: SCA; R_{ij}: Reciprocal effect, ** : significant at 1% level; * : significant at 5% level

3.8. Protein content:

Protein content of parents varied between 20.01% (Mor Toparlak) and 26.80% (Java) and protein ratios of the hybrids varied between 20.95% (Beyaz Toparlak x Mor Toparlak) and 28.90% (SF 08/03 x Ribera) (Table 5). Present findings comply with the results of Ceyhan et al. (2014a), Varankaya and Ceyhan (2012), Ceyhan (2006).

Lower GCA variance than the SCA variance indicated that non-additive gene effect and superior dominancy were effective on heredity of protein ratio (Table 5). Ceyhan et al. (2014a) in a study indicated that non-additive gene effect was effective on heredity of protein ratios in beans.

With regard to GCA of the parents for protein ratio, it was observed that while SF 08/03, Ribera and Java cultivars had a significant positive (p<0.01) value, Mor Toparlak and Beyaz Toparlak cultivars had a significant negative (p<0.01) value (Table 6). Therefore, SF 08/03, Ribera and Java cultivars with significant positive GCA values can be recommended for further breeding programs to be carried out to increase protein ratios.

Considering the SCA effects of the hybrids in F_1 generation, it was observed that all hybrids, except for one, had significant SCA effects. Therefore, “SF 08/03 x Ribera” (p<0.01), “SF 08/03 x Java” (p<0.05), “SF 08/03 x Beyaz Toparlak” (p<0.01), “Ribera x Java” (p<0.05), “Ribera x Mor Toparlak” (p<0.05), “Ribera x Beyaz Toparlak” (p<0.05) and “Java x Mor Toparlak” (p<0.05) hybrids with significant positive GCA effects were found to be promising genotypes to be used in further breeding programs for protein ratios (Table 6). In a previous study, Ceyhan et al. (2014a) also reported genotypes with significant positive GCA and SCA values for protein ratio.

Heterosis values for protein ratio in F_1 generation varied between -3.38% (Java x Beyaz Toparlak) and 17.85% (SF 08/03 x Beyaz Toparlak). While all hybrids had significant heterosis values for protein ratio, heterobeltiosis values of two hybrids were insignificant (Table 7).

Broad and narrow sense heritability in F_1 generation was respectively identified as 0.99 and 0.56 (Table 5). Medium narrow sense heritability indicated that besides environment, genetic variance was also effective on heredity of protein ratio. Significant non-additive gene effect on protein ratio indicated that selections should be initiated at late generations.

Table 7
Heterosis (%) values for investigated traits in full-diallel hybrid set

F_1 Hybrids	Seed Yield	Hundred Seed Weight	Protein Ration	Protein Yield
SF 08/03 X Ribera	48.97**	-5.60	17.27**	74.93**
SF 08/03 X Java	45.74**	-49.71**	7.14**	55.66**
SF 08/03 X MT	74.37**	3.83	13.98**	105.33**
SF 08/03 X BT	15.15	13.89**	17.85**	38.92**
Ribera X SF 08/03	22.61*	-35.69**	15.31**	41.49**
Ribera X Java	105.99**	-14.20**	2.88**	111.53**
Ribera X MT	38.07**	-14.97**	8.86**	53.56**
Ribera X BT	-17.63*	-36.34**	11.89**	-6.81*
Java X SF 08/03	25.55**	-49.71**	7.89**	35.31**
Java X Ribera	-1.51	-20.58**	13.53**	11.75*
Java X MT	55.35**	0.87	5.33**	71.71**
Java X BT	20.27*	10.38**	-3.38**	20.58**
MT X SF 08/03	40.34**	-3.24	3.85**	50.64**
MT X Ribera	28.73*	0.00	10.31**	45.13**
MT X Java	53.59**	4.35	3.51**	66.47**
MT X BT	-17.12*	-8.73**	1.32**	-16.42**
BT X SF 08/03	24.38*	10.56**	1.27**	28.93**
BT X Ribera	67.85**	29.58**	6.00**	79.79**
BT X Java	32.84**	26.78**	-2.25**	34.65**
BT X MT	-27.11*	-8.73**	-0.24*	-27.59**
Mean	31.82	-7.36	7.12	43.78

** : significant at 1% level; * : significant at 5% level

3.9. Protein yield.

Protein yields of the parents varied between 5.24 g plant^{-1} (Java) and 9.92 g /plant^{-1} (Beyaz Toparlak) and protein yields of the hybrids varied between 5.92 g /plant^{-1} (Java x Ribera) and 14.31 g plant^{-1} (SF 08/03 x Mor Toparlak) (Table 5). Present findings comply with the results of Varankaya and Ceyhan (2012).

With regard to protein yield, σ^2GCA was lower than σ^2SCA and $(H/D)^{1/2}$ ratio was greater than 1 (Table 5). Such findings revealed that non-additive gene effects and dominant gene effects were effective on heredity of protein yield.

Considering the GCA of the parents, while Mor Toparlak cultivar had a significant positive ($p<0.05$) value, Java cultivar had a significant negative ($p<0.05$) value (Table 6). Therefore, Mor Toparlak cultivar with significant positive GCA can be used as a parent in further breeding studies to increase protein yields.

With regard to SCA of the hybrids in F_1 generation, “SF 08/03 x Mor Toparlak” ($p<0.01$), “Ribera x Beyaz Toparlak” ($p<0.05$) ve “Java x Mor Toparlak” ($p<0.05$) hybrids with significant positive SCA effects were identified as prominent genotypes to be used in further breeding programs to improve protein yield of the beans. On the other hand, “Mor Toparlak x Beyaz Toparlak” hybrid had significant negative SCA effect (Table 6).

Heterosis values in F_1 generation for protein yield varied between -27.59% (Beyaz Toparlak x Mor Toparlak) and 111.53% (Ribera x Java) with a mean value of 43.78%. All of the hybrids had significant heterosis values for protein yield (Table 7).

Broad and narrow sense heritability for protein yield in F_1 generation was respectively identified as 0.90 and 0.02 (Table 5). Lower narrow sense heritability indicated that environmental factors significantly influenced heredity of protein yield. Significant effects of non-additive genes on heredity of protein yield indicated that selections for this trait should be performed at late generations.

4. Conclusions

It was concluded based on current findings that the present population had a sufficient variation for investigated agronomic traits. Non-additive genes and dominant genes were more effective on investigated traits. Further selections in this population should be considered together with seed yield and better be performed especially at late generations.

5. Acknowledgements

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Short-Term Impacts of Biochar Applications on Physico-Mechanic and Chemical Properties af Two Contrasting Textured Soils

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ABSTRACT

The effect of biochar applications on soil properties varies significantly depending on soil textures. Therefore, a pot experiment was carried out to investigate the effects of biochar (BC) amendment on some soil physico-mechanic and chemical properties, such as bulk density (BD), particle density (PD), mean weight diameter (MWD), aggregate stability (AS), Attarberg limits, soil pH, electric conductivity (EC), organic carbon (OC), total nitrogen (TN), and C:N ratio of two different textured calcareous soils (Clay and Sandy Loam). Biochar produced from sunflower residues were mixed with soils at the rate of 0, 1, 2 and 4%. All pots were watered to field capacity and incubated for 30 days. The results showed that biochar improved soil structural properties for both studied soils. Although mean weight diameter (MWD) was increased in clay soil, it was decreased in sandy loam soil. The liquid limit was increased by an increment of BC application rates in both soils, and the plastic limit was increased in single clay soil. BC affected selected soil chemical properties by decreasing soil pH, and increasing the soil EC, OC, TN, and C: N ratio, but no effect was detected on $CaCO_3$ content in both soils. Organic carbon mineralization ratio increased in the clay soil amended with BC, however, decreased in the sandy loam soil compared with the control sample. As a conclusion, the biochar amendment improved soil physico-mechanic properties of the studied soils. However, the effect on chemical properties was inconsistent

1. Introduction

Biochar is a charcoal produced by pyrolysis of biomass in a closed container at relatively low temperatures (<700° C) with restricted oxygen conditions (Lehmann and Joseph, 2009). Biochar amendment can mitigate the impact of climate change and is regarded as a promising strategy for soil carbon (C) sequestration (Lehmann 2007; Woolf et al. 2010). Due to its stability and low degradation rate in soil compare with other common organic matter resources, its effect on soil physical, chemical and biological properties may continue for a long time period (Atkinson et al. 2010).

The high porosity and a high surface area exceeding 400 m^2 g^{-1} of biochar were reported by (Brown et al. 2006), and thereby increasing the holding capacity of water and nutrient in soil (Ippolito et al. 2011). The results of many researchers showed that biochar amendment reduced soil bulk density by increase soil porosity and aeration (Tammeorg et al. 2014; Omondi et al. 2016). It helped to improve soil structure by producing more stable soil aggregate through the promotion of macroaggregate formation (Herath et al. 2013; Ouyang et al. 2013). Soil structure stability is affected by different factors, such as clay content, and amount and type of soil organic matter (Six et al. 2004). The stability of soil aggregate can protect soil organic matter by reducing the decomposition (Six et al. 2002).

Increasing of organic matter content by the addition of biochar can significantly enhance soil microbial activity, which plays the main role for stabilization and formation of soil macroaggregates (Lehmann and Joseph 2009). The increase in aggregate stability by addition of biochar was associated with an increase in physically protected C incorporated in macroaggregates at fine textured silt loam soil; however, at coarse-textured sandy loam soil biochar had no effect on aggregation (Wang et al. 2017). Pituello et al. (2018), found that promoting of aggregate stability by addition of biochar improve the physical fertility of the soil, especially with coarse-textured and low organic carbon contented soils. Soil conditions and feedstocks of tested biochars were effective in improving soil properties (Omondi et al. 2016).

Due to the role of biochar in increasing soil water holding capacity by increasing soil porosity, it has a

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certain effect in the limits of Atterberg (liquid and plastic limits), however, no more studies had explained biochar amendment effect on these limits adequately. About the effect of biochar on soil chemical properties, there is high variability of the result depends on the biomass used, the temperature during pyrolysis and residence time (Teβin, 2016). Biochar usually has alkaline (pH>7) activity (Lehmann and Joseph 2009), high ash contents, and high surface areas and could result in increased soil pH as reported by Novak et al. (2009). Thus, a lot of studies investigated about the effect of biochar amendment on acidic soil showed that soil pH was increased, e.g., (Tasneem and Zahir 2017). High content of ash in biochar can increase soil pH, due to the presence of readily soluble oxides of CaO, MgO, Fe_2O_3 in biochar (Koukouzas et al. 2007). However, oxidation of biochar could decrease the pH of the soil around the vicinity of biochar particles (Cheng et al. 2006). Soil EC increased significantly with biochar amendment in most of the research. This increase was attributed to the release of weakly bound nutrients of biochar in the soil solution (Chintala et al. 2013).

The C: N ratios of biochar vary widely and ranged between 7- 400, with a high mean of 61, and it is considered as a high N depleted (Lehmann and Joseph 2009). Since, C: N ratios increase immobilization of N occurs, biochar amendment to the soil add a supplemental amount to the both C and N stock (Clough et al. 2013). The mineralization of organic matter in the soil during the incubation period is an important indicator of soil microorganism activity. The objective of this study was to determine the short-term effects of biochar applications doses on improving the physico-mechanic and chemical properties of two different contrasting textured soils having poor aggregation properties.

2. Materials and Methods

Site description and soil sampling

Agricultural soil located at Central of Anatolia region, Konya plain (1016 m H), where clay soil from Sarıcalar Research and Application Farm (38°05'48.0"N, 32°26'23.0"E), and sandy loam from a soil plot at Çumra basin (37°33'38.3"N, 32°40'00.0"E) under cultivation were collected from the surface (0-20 cm) and used in this study (Table 1). Both textured soil samples used in the study were weak aggregated properties and low exchangeable-extractable sodium contents and with alkali reaction and no salinity problems (Bal et al. 2011; Şeker et al. 2016). Soil samples were sieved in situ by 4 mm sieve, and then after air-drying part of samples passed through a 2 mm sieve and experiment establishment at the laboratory in April 2018.

Preparation of biochar

Biochar produced from sunflower residues, and before the pyrolysis process dried in an oven at 70° C for 24 hours to remove moisture, thereafter, wrapped with aluminum foil to prevent the entrance of oxygen and then pyrolyzed in a muffle furnace at a temperature of 450° C for one hour. After cooling, the biochar was passed through 2 mm sieve and stored in a plastic container until the starting of the experiment. Biochar was a very high alkaline reaction (pH: 10.2) and EC value and C/N:25,9 (Table 1)

Table 1
Properties of soil and used material.

Soil parameters	Clay soil	Sandy loam soil	Biochar
Clay (%)	50.70	8.60	-
Silt (%)	36.00	14.00	-
Sand (%)	13.30	77.40	-
pH*, **	8.0	8.2	10.2
EC*, ** (dS m^{-1})	0.6	0.3	15.0
$CaCO_3$ (%)	13.2	11.9	10.6
OC (%)	2.3	0.9	62.1
N (%)	0.2	0.1	2.4
C/N	13.9	8.7	25.9
Field cap. (g g^{-1})	0.37	0.20	-

*(1:2.5) Dilution rate for soils, **(1:20) dilution rate for biochar

Incubation experiment setup

Soil samples of 3 kg based on a dry weight basis were completely mixed with biochar (BC) at a rate of 0%(control), 1, 2 and 4% for both soil texture, the mixtures were placed in the pots, then watered at field capacity and subsequently incubated for 30 days at 23±2°C. During the incubation period, after every 3 days, water losses were compensated by adding deionized water up to field capacity.

Statistical Analyses

The study was a pot experiment with four replications in accordance with a completely randomized plot design, and all data (means ± standard deviation) were analyzed by one-way ANOVA, and differences in means were compared by the least significant difference test at $P < 0.05$. All statistical analysis was carried out by (Minitab, 2013).

Soil Analyses

Soil texture was determined by Bouyoucos hydrometer method (Gee and Bauder, 1986). Soil bulk density (BD) was measured through the protocol developed by Jacobs et al. (1964), particle density (PD) was measured by pycnometer method (Blake and Hartge, 1986), and then soil total porosity was calculated by the relation between BD and PD (Danielson and Sutherland, 1986). Soil aggregation status was studied by a wet sieving method adapted by (Kemper and Rosenau, 1986). At the end of the incubation period, dry soil samples passed through a sieve of 4 mm, then put on the top of (2, 1, 0.5 and 0.25 mm) sieves, then transported to the Yoder machine and sieved for 10 minutes. Mean weight diameter (MWD), an index of soil aggregate stability was calculated according to the following equation (van Bavel, 1950):

$$MWD = \sum_{i=1}^{n} Xi * Wi$$

Where: Xi is the average diameter (mm) for particles in its fraction and Wi is the weight percentage of the fraction in the whole soil.

Aggregate stability values were determined by artificial rainfall simulator according to Gugino et al. (2009). The liquid limit was measured by penetrometer method after passing soil samples from 0.42 mm mesh sieve according to (TSE 1987). Plastic limit (PL), Liquid limit (LL) and Plasticity index (PI) was determined through an established method by (ASTM, 2010). Soil pH and electric conductivity (EC) (1:2.5) were measured in the laboratory after the end of incubation (Mclean 1982; Rhoades 1982). Calcium carbonate ($CaCO_3$) was determined by reaction with dilute hydrochloric acid in Scheibler calcium, by measuring the volume of emitted CO_2 from carbonates (Nelson 1982). Soil organic carbon (OC) was measured by a wet combustion method proposed by Smith and Weldon (1941). Total Nitrogen (TN) was determined by using the LECO CN-2000 device with Dumas dry burning method (Wright and Bailey, 2001). The mineralization rate of OC was detected in control treatments by calculating the rate between the inherent soil OC before incubation and the OC after one month of incubation, and for the BC doses by adding the contributing amount came from BC before and after the incubation period.

3. Results and Discussion

Physico-mechanic properties

The effect of biochar amendment at rates of 1, 2 and 4% on soil physico-mechanic properties of clay and sandy loam soils, such as bulk density, particle density, soil porosity, mean weight diameter, aggregate stability, liquid limit, plastic limit, and plastic index, which are presented in (Table 2). Soil bulk density was significantly decreased (P< 0.001) with increasing of biochar rates for both soils texture compared with the control treatments (Table 2). There are no significant differences between application rates of biochar in clay soil; however, BC 4% decreased bulk density by 5.8% in sandy loam soil. Particle density was decreased significantly (P<0.001) in clay soil only at BC 4% and no significant effect on sandy loam soil. The results of total porosity obtained from the relation between bulk and particle density significantly (P<0.001) increased in both soil texture, but no significant effect between rates of BC in clay soil. In the sandy loam, total porosity was increased with increasing of BC amendments and the rate of 4% had the highest value.

The results of mean MWD in clay soil significantly (P<0.01) increased with increasing of BC rates and the highest MWD was found at 4% by being increased nearly 33%, however, no significant effect between BC rates. Contrarily, in sandy loam soil, increasing of BC amendments affected negatively and significantly (P<0.001) decreased the MWD, and the lowest value was at 4% by being decreased by 33%.

Table 2
Effect of biochar on soil physical properties in clay and sandy loam soil

Properties	Clay soil				P Value
	Control	1%	2%	4%	
Bulk density (g cm^{-3})	0.95±0.00 a	0.91±0.00 b	0.91±0.00 b	0.91±0.00 b	***
Particle density (g cm^{-3})	2.56±0.00 a	2.58±0.01 a	2.56±0.01 a	2.49±0.02 b	***
Total porosity (%)	0.62±0.00 b	0.65±0.00 a	0.65±0.00 a	0.64±0.00 a	***
MWD (mm)	0.22±0.02 b	0.29±0.04 a	0.31±0.04 a	0.33±0.03 a	**
Aggregate stability (%)	7.88±1.32 c	15.44±0.97 b	17.82±1.26 a	13.65±0.79 b	***
	Sandy loam soil				
Bulk density (g cm^{-3})	1.20±0.01 a	1.21±0.00 a	1.19±0.00 a	1.13±0.01 b	***
Particle density (g cm^{-3})	2.50±0.03	2.54±0.01	2.53±0.01	2.51±0.02	NS
Total porosity (%)	0.52±0.00 b	0.52±0.00 b	0.53±0.00 b	0.55±0.00a	***
MWD (mm)	0.33±0.00 a	0.27±0.01 b	0.23±0.04 bc	0.22±0.01 c	***
Aggregate stability (%)	6.06±0.88 b	8.40±0.53 a	6.67±1.26 ab	6.29±0.43 b	**

Significant at ***P* <0.01, ****P* <0.001; NS: Not significant

The results of AS obtained from rainfall simulator experiment showed significantly (P<0.001) increased with increasing of BC rates in clay soil, and highest AS was at 2% by being increased 126%. Whereas in the sandy loam soil, AS significantly (P<0.01) increased 36.6% when only 1 % of BC was applied, but no significant effect at 2% and 4% application rates. Figure 1 shows the effect of biochar doses on Atterberg limits in clay soil. The liquid limit results showed a significant increase (R^2: 0.97, P<0.001) with an increase of BC rates, and the highest increase was 11% for clay soil when 4% rate was applied. The results of plastic limit were significantly increased (R^2: 0.99, P<0.01) with an increase of BC doses and plastic limit increased by 14% at 4% of BC. The plasticity index showed no significant increase (R^2: 0.57) with increasing of BC doses, however, the degree of plasticity was found in plastic class according to Leonards (1962).

Chemical properties

The results of the effect of applied biochar at rates of 1, 2 and 4% on soil chemical properties, such as soil pH, electric conductivity, calcium carbonate, total nitrogen, organic carbon, and C/N ratio are presented in (Table 2). Soil pH was significantly (P<0.001) decreased by increasing of BC doses, and the highest increase were at 4% rate of BC with 2.1% and 2.4% in both clay and sandy loam soils, respectively.

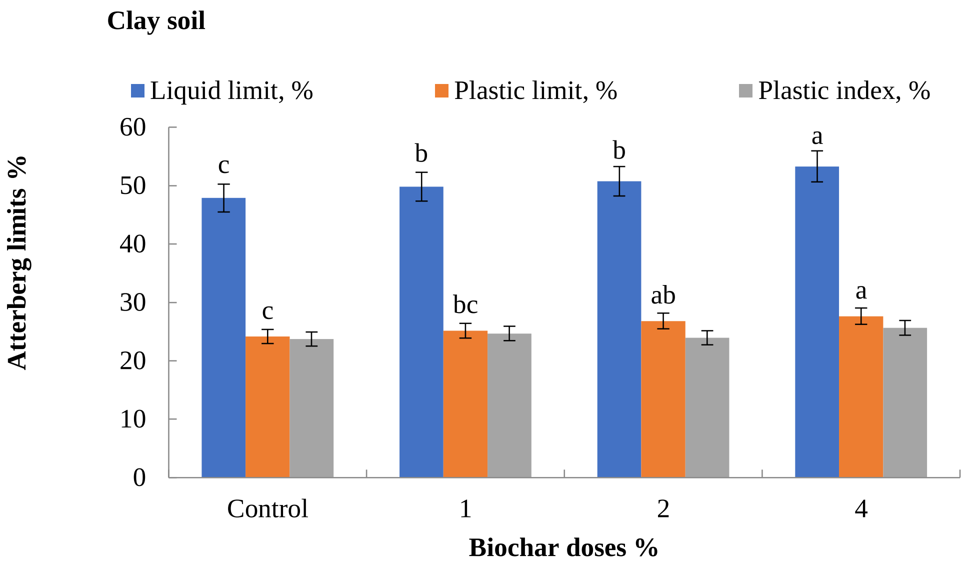

Figure 1
Illustration of liquid limit, plastic limit and plastic index of clay soil.

Table 3
Effect of biochar on soil chemical properties in clay and sandy loam soil

Properties	Clay soil				P Value
	Control	1%	2%	4%	
pH (1:2.5 H_2O)	8.02±0.00 a	7.89±0.02 b	7.88±0.00 b	7.85±0.00 c	***
EC (1:2.5 H_2O dS m^{-1})	0.57±0.03 d	1.04±0.019 c	1.33±0.006 b	2.07±0.078 a	***
OC (%)	2.41±0.01 d	2.95±0.03 c	3.34±0.08 b	4.16±0.12 a	***
$CaCO_3$ (%)	13.23±0.56	12.95±0.51	13.26±0.63	13.54±0.07	NS
Total nitrogen (%)	0.17±0.02 c	0.19±0.00 bc	0.21±0.01 ab	0.23±0.02 a	***
C/N	10.15±1.91 b	11.05±0.37 b	12.23±1.11 ab	14.92±1.34 a	*
	Sandy loam soil				
pH (1:2.5 H_2O)	8.20±0.01 a	8.07±0.01 b	8.04±0.00 c	8.00±0.01 d	***
EC (1:2.5 H_2O ds.m^{-1})	0.25±0.01 d	0.62±0.02 c	1.03±0.01 b	1.76±0.09 a	***
OC (%)	0.92±0.01 d	1.38±0.01 c	1.65±0.02 b	2.58±0.02 a	***
$CaCO_3$ (%)	11.90±0.40	11.66±0.27	12.33±0.28	12.31±0.40	NS
Total nitrogen (%)	0.12±0.00 c	0.16±0.00 b	0.17±0.00 b	0.18±0.00 a	***
C/N	4.95±0.27 d	6.73±0.32 c	11.38±0.93 b	14.13±0.91 a	***

Significant at *P <0.05, ***P <0.001; NS: Not significant.

The EC values were significantly (P<0.001) increased with increasing of BC rates in both soils of the study, and the rate of 4% had the highest EC value, which was increased by 263% and 604% in clay and sandy loam soils, respectively. CaCO3 content was not affected by the addition of BC in both soils. TN was increased significantly (P<0.001) by increasing BC rates in both soils, and the highest increase of TN was at 4% of BC in both soils, by a rate of 35.3% and 50% in clay and sandy loam soils, respectively. OC takes the same trend of nitrogen by significant increasing (P<0.001) with an increase of BC, and the highest values were at a rate of 4% by increasing rate of 72.6% and 180% in clay and sandy loam soils, respectively. The relationship between carbon and nitrogen which is expressed as C/N ratio showed a significant (P<0.05 and P<0.001) increase in clay soil and sandy loam soil with increasing of BC. It was found that the highest applied dose showed a higher value of C/N and C/N increased respectively by 47 and 185.4% in sandy loam and clay soil when biochar was applied at a rate of 4%. The mineralization rate of OC at the end of the short-term incubation period (one month) as illustrated in figure 3 and 4 was 11.5% at the clay soil, and 43% at sandy loam soil in control treatments, whereas at the BC amendments of 1, 2, and 4%, the mineralized OC was significantly increased (P<0.001) by the means of 23.9, 21.1, and 23.3% in a clay soil, and significantly decreased (P<0.001) by the means of 34.6, 15.8, and 23.6% in a sandy loam soil, respectively.

Discussion and conclusion

In both soils, the short-term amendment effects of biochar applications on the physico-mechanical properties were limited even if they were found significant statistically. The bulk density was decreased with concurrently increasing of BC doses and soil porosity in fine and coarse-textured soils, and these results are compatible with other studies (Lehmann and Joseph, 2009; Glab et al. 2016; Ningning et al. 2016). Due to the low density of biochar around 1.5 to 1.7 g cm^{-3} (Oberlin 2002) and 1.47 g cm^{-3} such as biochar made from pine wood collected from fire site (Brown et al. 2006), the particle density of our soils with 4% of BC amendment was significantly decreased. One of the mechanisms of soil aggregation is made by forming cation bridges between clay particles and soil organic matter (Juriga and Šimanský, 2018). In addition, biochar has high basic cation content (Rajkovich et al. 2012), therefore, its application to the soil can join clay and organic particles together by cation bridges (Bronick and Lal, 2005). In this study, the aggregation index of MWD was significantly increased with increasing of biochar doses only in clay soil. In contrast to the results of sandy loam soil, it was shown that MWD decreased with increasing of BC doses because of the weak bond between sand particle, although both soils have low exchangeable-extractable sodium contents (Bal et al. 2011; Şeker et al. 2016), which made a weak soil aggregate that cannot resist the wet sieving. Our results about the effect of biochar on MWD in sandy loam soil are in agreement with Fungo et al. (2017), who found that biochar did not affect on MWD alone, but when a combined application with green manure or urea showed a significant increase in MWD. Similarly, Herath et al. (2015) and Peng et al. (2016) founds that no effect of biochar amendment on soil micro-aggregates. However, the results of soil aggregate stability by rainfall simulator showed a significant increase in values of both soils compare with control, meaning that biochar amendment promoted the formation of more stable soil aggregate, which is resistant to degradation by rainfall drops. But when biochar doses were increased up to 4% in clay soil, as well as up to 2 and 4% in sandy, soil aggregate decreased compare with 1%, this was probably attributed to the effect of raindrops to reduce the particle size of biochar from certain types of biomass (Graetz and Skjemstad 2003). The liquid limit was significantly increased with increasing of BC doses in both soils. No more studies about the direct effect of BC on Atterberg limits have been carried out, however, it was reported that biochar can improve soil physical and hydraulic properties, such as soil porosity and soil water holding capacity (Şeker and Manirakiza 2020). Likewise, the result of the plastic limit in clay soil showed a significant increase for the same reason. Plasticity index results showed that there was no significant effect of BC amendment on soil plasticity; however, it was classified as plastic soils according to (Leonards 1962) classification. According to (Mitchell 1976) and depending on the results of Atterberg limits, the estimate clay mineral of our studied clay soil is kaolinite.

The pH of biochar considerably depends on the type of used feedstock and pyrolysis temperature, and it has been well documented that biochar amendment can significantly alter the pH of the soil (Lehmann and Joseph 2009). Although our results showed that pH of BC that used in this experiment was up to 10.2, soil pH was significantly decreased with increasing of BC doses as compared with the control in both soils. Cheng et al. (2006) reported that pH of biochar can be decreased to a value of 2.5 after incubation at 70° C in a short time period of four months and attributed that to the effect of incubation on increasing of oxidization process, thereby decreasing soil pH around biochar particle. About the effect of BC amendment on soil EC, our results showed a remarkable increase in soil EC with increasing of BC doses, and these results are agreement with numbers of studies such as (Lehmann and Joseph 2009; Tasneem and Zahir 2017) this increase in soil EC could be attributed to the release of weakly bound nutrients of biochar in the soil solution (Chintala et al. 2013).

The OC was significantly increased with BC amendment in both soil, this was expected because of the high sequestration of C in biochar. The increasing rate was more in sandy loam soil than clay soil, because of the inherent low content of OC in sandy soil. The TN content was increased significantly in both soils, but the increasing rate was higher in sandy soil than clay soil. Our results of TN and OC are in agreement with Laird et al. (2010), who found that biochar amendment significantly increased TN and OC. The C/N ratio was significantly increased in both soils under cultivation with increasing of BC, due to its high C content in biochar.

The results of mineralized OC illustrated in figures 3 and 4 have shown that the mineralization rate of control treatments in sandy loam soil was approximately fourfold more than that at a clay soil. This supposed to be because of the effect of clay by making colloidal complexes led to reducing the mineralization rate in clay soil (Six et al. 1998; Sparks 2003). Whereas at the BC amendments, our results have shown an increase in the mineralization rate of clay soil in comparison with control, however, it was relatively still at a stable rate with increase of BC doses, may be because of the high activity and number of microorganisms in clay soils still sufficient even in with increasing of OC in soil (Lehmann et al. 2011). While the opposite occurred in a sandy loam soil the BC amendments had an effect by decreasing the rate of mineralization in significantly compared with control, due to higher mineralization ratio of the control sample non-amended with BC at sandy loam soil. Although the organic carbon content of the sandy loam soil is lower than the clay soil, the mineralization rate in the control sample in sandy loam soil was found higher than the clay soil. The reason for this is considered to be due to bonding of clay colloids and humus complexes (Sollins et al. 1996; Six et al. 1998).

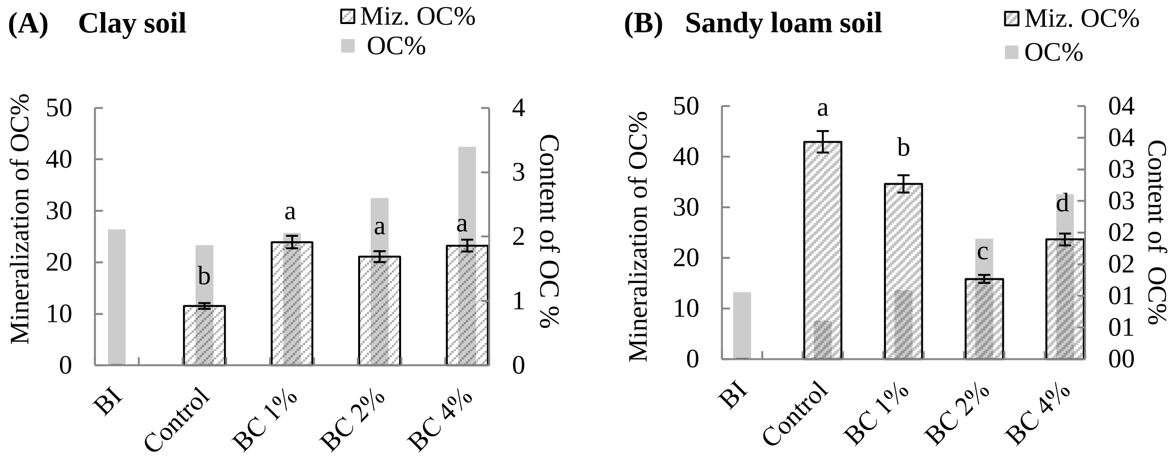

Figure 3
Illustration the effect of incubation period on mineralization of organic carbon in clay and sandy loam soils; BI (Before incubation)

This study was carried out under laboratory condition to investigate the effect of biochar amendment in a short-term period on some soil physico-mechanic and chemical properties. The results obtained showed that BC amendment had a positive effect on soil structural properties, by enhancing soil porosity, reducing BD, and increasing soil aggregation in both soils of study. However, MWD was significantly increased only in clay soil and decreased in sandy loam soil, due to the weak bind between BC and sand particles. Our results of soil LL test had shown a significant increase with increasing of BC doses in both studied soils. Which could be attributed to the benefits of BC to promote the soil aggregates and increase the soil porosity, thereby, increasing the soil water storage capacity and raise the liquid limit of soil. The results of PL detected at a clay soil showed the same trend with a significant increase by increase of BC doses. Whereas the results of plastic limits did not show a significant effect because of increase both LL and PL. The chemical properties showed that the benefit of biochar to decrease soil pH in the study soils, which had relatively high lime content. The BC additions were increased C sequestration capacity by significantly increasing of soil OC. The rate of OC mineralization was more at sandy loam soil than clay soil, due to the effect of clay to reducing OC that process, and the mineralization rate still relatively stable even with an increase of BC doses. Whereas in sandy loam soil BC doses were significantly decrease the mineralization rate by increase the sequestration of OC. Although that BC amendment had a negative effect on soil EC and C:N ratio by raising their values significantly, but generally it improves soil physico-mechanic and chemical properties in both soils. Overall, biochar effect was more pronounced on the sandy loam soil than clay soil.

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The Response of Dry Bean to Water Stress at Various Growth Cycles in a Semi-Arid Region

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ABSTRACT

Poor irrigation management is resulted from some reasons such as lack of information relevant to the crop water use. That kind of information is necessarily prerequisites for both planners and producers to obtain irrigation program to minimize the yield losses under water stress conditions. A two-year, 2013-2014 growing season, field experiment was performed to determine the response of dry bean to the water deficiency in different growth stages at Konya plain of Turkey. The study was organized as randomized complete block design with three replications. Vegetative (V), reproductive (R), and pod filling-maturation (P) three plant growth cycles as were examined with including rain-fed total eight irrigation treatments were researched. A 100% crop water requirement (VRP) was considered full-irrigation treatment. Irrigation was not performed during vegetative, reproductive, and pod filling-maturation cycles or during a combination of those stages in other treatments. In results, depending on the irrigation treatments, actual evapotranspiration (ETa) for 2013 and 2014 varied from 104 to 544 mm and from 110 to 558 mm, respectively.

The average crop coefficients (K_c) among the years were 0.75 for vegetative, 1.01 for reproductive, and 0.82 for pod filling-maturation stages. Depending on irrigation time, as decreasing the irrigation water resulted reducing seed yield. It was obvious that higher seed yield as well as yield components obtained full irrigation at entire growing season, which was preferable. An alternative to full irrigation in whole growth stages particularly in areas with insufficient water resources, performing full irrigation till initial of the filling-maturation cycle and then ending irrigation can be highly recommended as ideal, as it resulted water saving of 38%, and rise 27% in irrigation water use efficiency (IWUE) as well as 20% seed yield loss by comparison to full irrigation.

1. Introduction

Water is increasingly being a scant tool in agriculture as the competitions between industrial, municipal, and environmental water utilizations is growing. In water shortage climates, possibly water availability is the vital important factor limiting growing of agriculture (Fernandez et al. 2002, Ferreira and Carr 2002, Deng et al. 2006, Zhou 2003). In such ecologies, inadequate irrigation practices is one of the main reasons affecting water scarcity increase since about more than 85% of available water has been used in irrigation (Er-Raki et al. 2010). For contribution feed security, efficient water use as a consequently facilitation more lands under irrigation is necessarily prerequisites. Detail information relevant to the crop water consumption, critical crop growth cycles as well as correct irrigation program for maximum crop yield is very important role to play to design the water use of crop production. Besides that, information about available water amount to meet the crop needs is also very important. Crop water sue differs through crop growing period due the variations in crop cover and climate conditions (Allen et al. 1998).

The focusing on ET_a or total water consumption is the most fundamental issues for irrigation program. The field water budget is a well-known parameter considered to determine ET_a, that rises with and increasing the number of irrigation from one to several times. K_c, mainly varies by specific crop properties and less affected from clime, and ET_o representing almost whole effects of weather are used also for calculation of ET_a under stress conditions (Allen et al. 2005). Besides that, K_c is also influenced from crop and water management as well as the characteristics of soil and irrigation system. The determination of k_c under local environmental conditions is the back bone for improving the planning and success of irrigation management in various field crops (Kang et al. 2003). To estimate reference evapotranspiration (ET_o), data obtained from Class A Pan are extensively used worldwide (Grismer

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et al 2002, Irmak et al 2002). However, a reliable estimation of ET_o using pan evaporation (E_{pan}) is necessarily perquisites for accurate determination of pan coefficients (K_{pan}).

The Konya Plain having 8% of Turkey's arable lands with limited water resources has a semi-arid climate. Rainfall in the Konya Plain is none uniform and occurs around the winter months, hence limiting the preference of annual summer crops to very few. For crop production during this period irrigation is beneficial and most of the water used is obtained from groundwater reservoir. More than 75% of the total fresh water resources available for agricultural activities are used. For this reason, agro-research programs on water productivity and water conservation should be implemented in Konya plain (Yavuz et al. 2015). In Middle Anatolia Region, dry bean is considered one of the less water-consuming crops by comparison to the sugar beet, carrot, and corn plants.

Dry bean, growing worldwide, is rich supply of high-quality protein, and well-known top dry bean productions countries are Myanmar, India, Brazil, and China. In accordance of 2019 records, about 1% of the world production was obtained from Turkey (FAO 2020). In that production year, bean production was around 0.225 million ton under open field conditions (TUIK 2020). The share of Konya in production of Turkey was about 28% (0.06 million ton). It is impossible to obtain economical seed production without irrigation in both Konya plain and other parts of Turkey. Water scarcity and energy cost of water pumping during irrigation processes are two important reasons forced farmers to be shorten the irrigation number in Konya region. Those reasons have pushed producers as well as water organizations to focus on deficit irrigation practices for reducing water utilizations in agriculture.

The main target in deficit irrigation strategy is improving the water efficacy for obtaining higher crop production by unit applied water (Fereres and Soriano 2007, Yavuz et al. 2020, Yavuz et al. 2021). In such deficit irrigation, crops are exposed to the certain level of water stress conditions in whole or particular crop growing cycles (English and Raja 1996). In the literature reviews, water deficiency during the periods of flowering and pod filling is very critical for dry bean production in Mediterranean environments (Boutraa and Sanders 2001, Munoz-Perea et al. 2006, Ninou et al. 2013, Ucar et al. 2009). In those growing cycles, rainfall pattern is not uniform in Mediterranean region so in case of irrigation water stress has resulted drops in flowers and pods. On the other hand, crops are not equally sensitive to water stress in whole cycles of crop vegetation period. The sensitivities of crops to the water deficiency vary during the growing stages. In areas where water supplies are limited timing of water deficiency therefore is key issue for correct irrigation water management.

In the literature citations, information relevant to the ET_a, K_c, and k_y as a function of growth cycles for different irrigation doses effect on dry bean response to yield is insufficient under growing environments of Turkey. Knowledge about K_c and K_{pan}, very important for irrigation program in regional basis is particularly almost none in some developing countries including Turkey.

The aims of the current study are as follows: (1) determination of the ET_a values and seed yield for dry bean for different irrigation treatments; (2) developing the K_c, K_{pan}, and k_y values from water using data for actual growing and regional climatic conditions to be used in irrigation scheduling and management at a regional scale.

2. Materials and Methods

Experimental Area

The study was performed at the research field belonging Faculty of Agricultural, University of Selcuk that is situated at Konya province having 38°58′N latitude, 32°06′E longitude, and 1006 m above sea level during the periods 2013-2014. The soil of experimental area is clay-loam (CL) with Entisol and is poor organic matter, the field capacity of 0.42 $m^3\ m^{-3}$, and the permanent wilting point of 0.26 $m^3\ m^{-3}$ as a consequent total usable water for the upper 0.6 m of the soil profile is around 96 mm (Table 1) as well as slope of site being less than 0.15%.

Table 1
Some physical and chemical properties of the experimental site soil (The values are average for 0-60 cm soil depth)

Parameter	Value and unit
Texture	Clay-loam
FC (field capacity)	0.42 $m^3\ m^{-3}$
PWP (permanent wilting point)	0.26 $m^3\ m^{-3}$
Zr (root zone depth)	0.6 m
Mean bulk density	1.3 $g\ cm^{-3}$
TAW (total available water)	96 mm
RAW (readily available water)	38.4 mm
P (soil water ET deficit factor)	0.40
pH	7.74
Organic Matter	1.57 %

The experimental site is typical semi-arid environment having dry or hot summers, and cold and snowy winters. In accordance of long-year climate records including 1960-2013, average annual precipitation is around 323 mm but, 25% of such rainfall has observed during the May-August in Konya plain. The prevailing wind orientation is NW to NNW. As seen in Table 2, climatic data during the vegetation period of 2013-2014 were in line with the historical average for the plain.

Table 2
Variations of meteorological parameters of region during experimental years

Months		Mean max. temp. (°C)	Mean min. temp. (°C)	Mean wind speed (m s^{-1})	Mean Relative humidity (%)	Precipitation (mm)	Mean solar radiation (MJm^{-2}day^{-1})	Mean daily sunshine (h)
May	2013[a]	25.2	11.4	2.2	59.8	46.0	23.5	7.8
	2014[b]	24.9	8.6	2.0	56.4	6.4	24.3	8.5
	53 years	22.2	8.5	2.2	55.9	43.8	25.0	8.5
June	2013	28.4	14.4	2.9	47.8	8.8	25.8	10.6
	2014	26.4	12.5	2.6	55.9	55.6	24.9	9.3
	53 years	26.6	12.7	2.5	48.4	22.9	27.8	10.4
July	2013	29.5	17.3	3.3	40.1	5.4	27.2	11.1
	2014	32.0	16.7	3.2	44.3	9.6	27.7	11.3
	53 years	30.0	15.9	2.8	42.1	6.8	28.7	11.4
August	2013[c]	30.5	17.2	2.9	38.6	-	26.6	11.0
	2014[d]	31.6	17.7	3.2	42.5	2.2	25.1	11.3
	53 years	29.9	15.4	2.6	42.9	5.5	26.6	11.1
Seasonal average/ total	2013	28.4	15.1	2.8	46.6	60.2	25.8	10.1
	2014	28.7	13.9	2.8	49.8	73.8	25.5	10.1
	53 years	27.2	13.1	2.5	47.3	79.0	27.0	10.4

[a] Calculated from the data between 11 and 31 May
[b] Calculated from the data between 16 and 31 May
[c] Calculated from the data between 1 and 18 August
[d] Calculated from the data between 1 and 21 August

The meteorological data used in this study was obtained from the automatic meteorological station (Vantage Pro2, Davis Instruments, CA) mounted at the experimental site. Air temperature, precipitation, relative humidity, atmospheric air pressure, solar radiation, and wind speed at a height of 2 m were measured hourly by that station. Those data were controlled for reliability analysis as suggested by Allen et al. (1998).

Irrigation System

The trickle irrigation system was used for water application for crops. That system was installed through the experimental plots just before the crop growing season in both years. The lateral tubes were placed on each plant row with 0.5 m apart at space of almost 5-10 cm apart the plant stem. The laterals were in-line pressure regulating emitters producing discharge of 4 l h^{-1} for a pressure of 1 kg cm^{-2}. The space between drippers was preferred as 0.40 m by considering properties of soil (Keller and Bliesner 1990). The target volume of irrigation water was measured by using water meters connected to the each plot. The irrigation water source was deep well having water table depth of around 30 m in experimental site.

Irrigation Treatments

The timing of irrigation within the critical crop cycles was considered in the experimental design. There were three cycles namely vegetative (V), reproductive (R), and pod filling-maturation (P) were examined to determine irrigation scheduling. The reproductive stage began by the occurrence of floral buds and finished by full-length pods in bottom nodes (Doorenbos and Kassam 1979, Nielsen and Nelson 1998). The growing period was considered as about 14-week: 5-week vegetative period (from establishment to the occurrence of floral buds), 4-week reproductive period (from the occurrence of floral buds to the end of pod development), and 5-week pod filling and maturation period (from the end of pod development to harvest) in both experimental years. The details of the experimental treatments are presented in Table 3. The practice of full irrigation, 100% ET, in each of those stages was planned as VPR.

Table 3
Irrigation treatments applied in the study

Experimental treatments	Growth stages: Vegetative (V)	Reproductive (R)	Pod fill and maturity (P)
VRP	I	I	I
VR	I	I	0
VP	I	0	I
RP	0	I	I
V	I	0	0
R	0	I	0
P	0	0	I
Rain-fed	0	0	0

I, full irrigated at a given stage; 0, irrigation omitted.
Vegetative growth period: 11 May-17 June (38-day) in 2013, and 16 May-20 June (36-day) in 2014.
Reproductive period: 18 June-13 July (26-day) in 2013, and 21 June-18 July (28-day) in 2014.
Pod fill-maturation period: 14 July-18 August (36-day) in 2013, and 19 July- 21 August (34-day) in 2014.
Entire growth season: 100-day in 2013, and 98-day in 2014.

Irrigation was done only at certain growth cycles and ignored at other growth cycles till end of the targeted growth cycle in other treatments. Whole experimental plots were irrigated with the same as VPR treatment. Irrigation at all growth cycles was done by irrigation water needed to reach the 0-60 cm soil depth to the field capacity moisture level. Irrigation was started when around 40% of the total available was used at the top 0.60 m of the soil profile for the VPR treatment.

Agronomy

The current experiment was organized in a randomized block design with three replications. All plots had five rows with 5 m long and at a space of 50 cm. Around 2.5 m spacing was left between plots to protect water entrance towards to plots. Dry bean seeds were sown manually on 11 May 2013 and 16 May 2014 with a density of 25 seeds per m^2. As a basal fertilization, nitrogen and phosphorus were given and mixed through the soil by a disk harrow. The application doses were 80 kg N ha^{-1} as $(NH_4)_2SO_4$ and 50 kg P_2O_5 ha^{-1} as superphosphate. The crop was kept free of weeds by hand hoeing in case of needy. Beans were harvested when plants were physiologically matured on 18 Aug. 2013 and 21 Aug. 2014. However, the rain-fed and V treatments were harvested approximately 10 days earlier than other treatments in both the years because of differences in maturity resulting water stress.

Measurements

The soil water contents were monitored using a profile probe (model PR2, Delta-T, UK) at a depth of 0.2 m which increments to 1.0 m prior to and after irrigation from each plot during the growing season. In addition, the soil moisture content was recorded at sowing, at every 7-day frequency and at the time of harvest process. One access tube was placed in every treatment. The profile probe was calibrated in accordance of gravimetric soil analyses simultaneously with the probe readings at whole tubes across the experimental site before the application of first irrigation.

Following water budget equation as suggested by James (1988) was applied to calculate actual evapotranspiration (ET_a) with constant 7-day duration for different irrigation levels:

$$ET_a = I + P + C_r - D_p - R_f \pm \Delta S \quad \dots \quad (1)$$

Where I is the applied by irrigation for individual parcels (mm), P is the rainfall amount (mm), C_r is the capillary movement upward direction (mm), D_p is the amount of water by deep percolation (mm), R_f is the amount of runoff (mm), and ΔS is the variation in soil moisture status (mm). Rainfall as daily was recorded in the research site by a digital weather platform. C_r was ignored due to the no upward water movement to the soil rooting systems in the experimental site. In this study, R_f was assumed to be zero since there were ridges between the adjacent plots preventing run-off and run-on. ΔS was determined by moisture monitoring in the soil profile having depth of 60 cm. Amount of applied water for each treatment by irrigation was not higher than field capacity of soil so seepage as percolation was counted out.

The addition of different irrigation treatments to the evapotranspiration was calculated by Equation (2) as suggested with Howell et al (1990):

$$I_{rc} = \left(\frac{I}{ET_a}\right) \times 100 \quad (2)$$

In such equation Irc is the irrigation water which meets evapotranspiration (%).

Water use efficiency (WUE, kg m^{-3}) and the irrigation water use efficiency (IWUE, kg m^{-3}) were calculated by equations (3) and (4) for determination of the performance of irrigation in the treatments:

$$WUE = \frac{Ya}{ET_a} \quad (3)$$

$$IWUE = \frac{Ya - Ya_{rainfed}}{I} \quad (4)$$

Where Ya is the seed yield of the treatments (kg ha^{-1}), Yarainfed is the seed yield of the rain-fed plot (kg ha^{-1}), ETa is the seasonal crop water use (m^3 ha^{-1}), and I is the seasonal applied irrigation water (m^3 ha^{-1}).

Statistical Evaluation

Yield and quality parameters affect on treatments was determined by analysis of variance (ANOVA). For comparing and ranking means of the treatments, Duncan's test was applied. Differences were declared with a significant at $P < 0.05$. The analysis of variance was applied with the SPSS 22.0 computer program.

3. Results and Discussion

Rainfall, Applied of Irrigation Water, and Crop Water Use

The total rainfall during the vegetation period of dry bean was found as 60.2 and 73.8 mm in 2013 and 2014, respectively (Table 4). Rare rainfall was seen within the growing period, especially during the reproductive and pod filling and maturation cycles in both years. The total rainfall between May and August in both years was slightly less than the long-year average seasonal precipitation. A large portion of the rainfall in both experimental years was seen during the vegetative growth cycle of the crop.

Table 4
The seasonal amount of irrigation water (I), precipitation (P), actual evapotranspiration (ET_a), and irrigation compensation (I_{rc})

Treatments	I (mm)		P^a (mm)		ET_a (mm)		I_{rc} (%)	
	2013	2014	2013	2014	2013	2014	2013	2014
VRP	501	514	60.2	73.8	544	558	92	92
VR	312	320	54.8	69.2	414	430	75	74
VP	280	269	58.4	66.8	311	302	90	89
RP	354	348	6.2	11.8	391	387	91	90
V	102	115	54.0	62.0	199	221	51	52
R	228	241	0.8	7.2	331	350	69	69
P	162	169	5.4	4.6	184	195	88	87
Rain-fed	-	-	-	-	104	110	-	-

[a] Amount of precipitation in each growth period

The amount irrigation water depended on irrigation treatments varying from 102 to 501 mm in 2013 and from 115 to 514 mm in 2014. The total irrigation water application for treatments was influenced by the amount and uniformity of the rainfall within the growing season. The highest applied irrigation water was found in the VRP treatments for both study years. However, the seasonal applied irrigation water in the V treatment was found minimum resulting from lower evaporative demand, mostly met from the rainfall at the beginning of the plant development. In result, the amounts of irrigation water for whole treatments were different due to variations in the soil moisture content and rainfall at a specific stage of the plant development period.

The seasonal ET_a values were found between 104 and 544 mm in 2013 and between 110 and 558 mm for 2014 in whole growing time of 100 and 98 days, respectively. The maximum actual evapotranspiration was determined from VRP irrigation treatment for both the years. Some studies have demonstrated marginally less water uses of dry bean for a 90- to a 100-day season varying from 350 to 500 mm due to the differences in the soil, environment, and crop variety (Allen et al 2000). Calvache et al. (1997) stated a crop water consumption as 447 mm of dry bean having growing period of 122-day, while Munoz-Perea et al (2007) found crop water requirements of 318 mm of dry bean cultivar “NW 63” and 457 mm of cultivar of “Othello” at full-irrigation treatments in Kimberly, ID. Nielsen and Nelson (1998) added that ETa values are between 265 and 455 mm for black bean which was grown in conditions of eastern Colorado having 183 mm of irrigation water with no rainfall. In the current study, the relatively high seasonal crop water use values depend on many factors such as environment, water resources, soil, topography and so on.

In the current work, a large parts of evapotranspiration was supported by water application by irrigation. Irrigation compensation (I_{rc}) ranged between 51 and 92% in 2013, and 52 and 92% in 2014. The I_{rc} value of treatment irrigated at all growth periods was higher than those watered at the individual growth periods. As expected, well-watered plants consume greater water as it is more abundantly usable, so the plants do not experience the water deficiency. The proper irrigations control the great fluctuation in plant water stress resulted by insufficient watering (Radin et al. 1989). The fact that 82% of water use for pumpkin is contributed by irrigation in the Konya region as reported by Yavuz et al. (2015).

Relationship between ET_a, ET_0, ET_{pan}

ETa of the VRP, full irrigation, treatment determined by the soil water budget equation, ETo calculated using the FAO Penman–Monteith formula, and the Epan values obtained from Class-A Pan for the 2013 and 2014 growing seasons of dry bean are shown as means of one week in Figure 1, respectively. The values of ETa varied from 3.3 to 8.1 mm day^{-1} during the growing season in 2013. It varied from 3.2 to 8.7 mm day^{-1} in 2014. Those ET_o values ranged from 5.1 to 7.8 mm day^{-1} in 2013 and from 4.8 to 8.1 mm day^{-1} in 2014. The maximum ET_a and ET_o values were measured in the reproductive periods of dry bean in both years. The seasonal ET_o value was found as 633.9 mm in 2013 and 654.0 mm in 2014. The E_{pan} values for 2013 and 2014 varied from 5.7 to 8.6 mm day^{-1} and from 5.2 to 9.3 mm day^{-1}, respectively. The seasonal E_{pan} value was found as 724.2 mm in 2013 and 734.8 mm in 2014. The seasonal and weekly E_{pan} values were greater than the corresponding ET_a and ET_o values in both years because of climatic parameters such as high temperature and low humidity.

For estimation of the *Kc* values on a weekly basis, the real ET_a values (VRP treatment) were divided to the corresponding ET_o values. The highest ET_a value as expected was obtained from the VRP treatment with enough water amount for crop water consumption. This value was decreased step by step for other irrigation treatments due to changes in the water use and evaporative requirement of the crop. Hence, the ETa ratio for the VRP treatment can be considered as the highest crop water use and thus it was used for calculation of the *Kc* values. The average values of crop coefficients in examined years were 0.75 for vegetative, 1.01 for

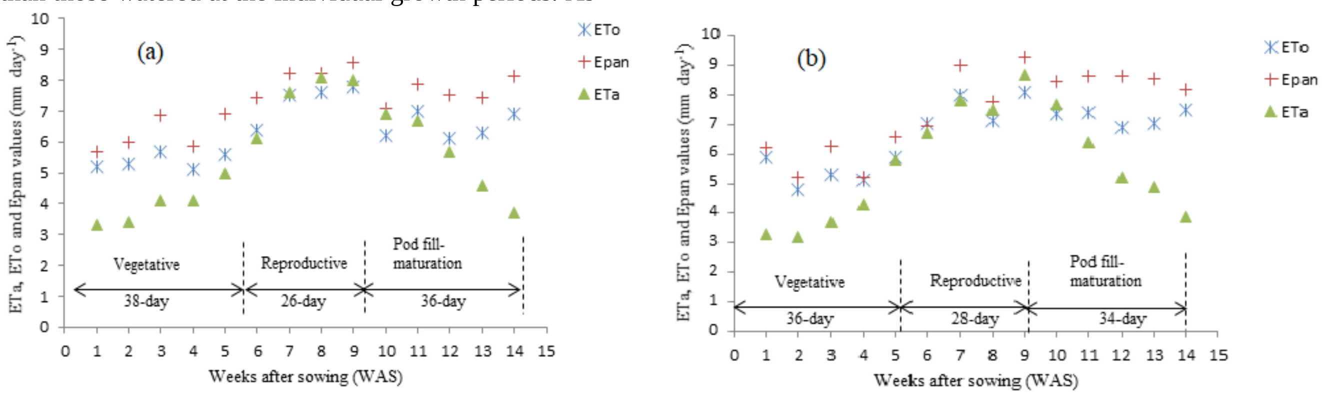

Figure 1
Time course evolution of ET_o, E_{pan} and ET_a during growing season (a,2013; b,2014)

reproductive, and 0.82 for pod filling-maturation stages. The mean Kc was estimated as 0.85 for the all season (Table 5). The estimated Kc values almost conformity with the values reported by the FAO 56 for dry bean (Allen et al. 1998).

The values of K_{pan} were computed from weekly ET_o and E_{pan} values and were given in Table 5. In present work, K_{pan} was between 0.85 and 0.92 during both crop growth periods. The seasonal K_{pan} values were 0.87 in 2013, 0.90 in 2014, and 0.89 in 2013–2014.

Table 5
Crop coefficients (K_c) and pan coefficients (K_{pan}) in both the growing season

Growth stage	K_c			K_{pan}		
	2013	2014	Average	2013	2014	Average
Vegetative	0.74	0.75	0.75	0.86	0.92	0.89
Reproductive	1.01	1.01	1.01	0.90	0.92	0.91
Pod fill-maturation	0.85	0.78	0.82	0.85	0.85	0.85
Entire season	0.86	0.83	0.85	0.87	0.90	0.89

Yield Parameters and Water Use Efficiency

The analysis of variance showed that in exception of the 1000-seed weight, whole parameters insignificantly influenced by years (Table 6). The year × treatment interaction was also found not significant for all the parameters at $P < 0.05$ levels. Therefore, the results were assessed in combined years (2013 and 2014) considering the seed yield, yield components, WUE, and IWUE.

Average among years, the seed yield, yield components, and the WUE and IWUE findings are presented in Table 7. Timing of water stress on seed yield of dry bean was found significant ($P<0.05$). The maximum seed yield as average 2362.5 kg ha^{-1} was determined from full-irrigated treatment during both the growing seasons. Water deficiency through different growing period resulted variations in seed yields obtained in other treatments.

The treatments introducing irrigation water at only one phonological cycle led to significantly different seed yield values in both years. Averaged over the years, the highest seed yield as 1213.6 kg ha^{-1} was found at irrigation water applied only at the reproductive cycle, whereas the minimum seed yield as 475.3 kg ha^{-1} was determined for irrigation water applied only at the pod filling-maturation cycle. The P treatment showed a significant reduction (–80%) in the seed yield by comparison to full irrigation during whole the growing period.

Table 6
Mean squares from the variance analyses of the yield and yield components in combined years

Source	d.f.[a]	Seed yield	Pods $plant^{-1}$	Seeds pod^{-1}	1000-seed weight	WUE	IWUE
Blocks (B)	2	4100.2^{ns}	0.25^{ns}	0.03^{ns}	36.1^{ns}	0.001^{ns}	0.001^{ns}
Years (Y)	1	57546.7^{ns}	0.10^{ns}	0.0004^{ns}	616.3^{*}	0.0004^{ns}	0.0001^{ns}
Error 1	2	9526.5	0.23	0.051	17.5	0.002	0.003
Treatments (T)	7	3366463.8^{**}	42.3^{**}	1.83^{**}	5830.2^{**}	0.072^{**}	0.107^{**}
Y x T	7	23882.1^{ns}	1.03^{ns}	0.025^{ns}	133.4^{ns}	0.002^{ns}	0.004^{ns}
Y x B	2	9526.5^{ns}	0.23^{ns}	0.051^{ns}	17.5^{ns}	0.002^{ns}	0.003^{ns}
Error 2	28	18464.5	0.46	0.029	69.8^{ns}	0.002	0.004

[a] Degrees of freedom for combined over 2 years.
[ns] Non-significant.
[**] Significant at the 1% of probability level ($P<0.01$).
[*] Significant at the 5% of probability level ($P<0.05$).

Table 7
Seed yield, yield components, WUE and IWUE

Treatments	Seed yield (kg ha^{-1})	Relative seed yield (%)	Pods $plant^{-1}$	Seeds pod^{-1}	1000-seed weight (g)	WUE kg m^{-3}	IWUE kg m^{-3}
VRP	2362.5a	100.0	11.7a	3.2a	334.8a	0.43a	0.44b
VR	1884.8b	79.8	11.7a	2.8b	302.7b	0.45a	0.56a
VP	884.9e	37.5	7.9c	2.5cd	286.7c	0.29cd	0.28c
RP	1552.8c	65.7	9.9b	2.7bc	334.4a	0.40ab	0.41b
V	737.1e	31.2	8.5c	2.0e	264.4d	0.35bc	0.57a
R	1213.6d	51.4	10.6b	2.4d	283.2c	0.36bc	0.46ab
P	475.3f	20.1	6.3d	1.8ef	279.3c	0.25d	0.21c
Rain-fed	122.9g	5.2	4.2e	1.6f	246.9e	0.11e	-
Average	1154.2	-	8.8	2.4	291.5	0.33	0.42
Cv(%)	11.8	-	7.7	7.2	2.9	13.5	15.1

In the treatments involving irrigation during two phonological stages, the relatively high seed yields were obtained from the VR treatment counting on the ignorance of irrigation at the pod filling-maturation cycle in both years. This finding indicated the relative resistance of dry bean to soil water deficiency at the pod filling-maturation stage and is generally conformity with the results obtained by Nielsen and Nelson (1998) who experimented on black bean. However, the ignoring of irrigation only during the reproductive stage (VP treatment) resulted much less values of the seed yield than those obtained with the RP treatment (water ignorance during the vegetative stage) and the VR treatment (water omission during the pod filling-maturation) (Figure 2). The VP irrigation treatment (water omission during the reproductive stage) reduced the seed yield by about 63% by comparison to VPR treatment (full irrigation) (Table 7).

The periods of water stress during the reproductive period of the dry bean led to significant losses in the seed yield (Boutraa and Sanders 2001, Munoz-Perea et al. 2006, Nielsen and Nelson 1998, Pimentel et al. 1999, Ramirez-Vallejo and Kelly 1998).

The irrigation treatments had significant effect on yield components of dry bean such as number of pods per plant, number of seeds per pod, and 1000-seed weight ($P<0.05$). The number of pods per plant ranged between 11.7 (VPR and VR treatments) and 4.2 (rain-fed treatment). The maximum numbers of seeds in pod were obtained (3.2 seeds per pod) in the VPR treatment followed by the VR (2.8 seeds per pod) and RP (2.7 seeds per pod) treatments. The lowest numbers of seeds per pod (1.6 seeds pod^{-1}) were observed when water stress was available at all growth periods (rain-fed treatment) and the vegetative + reproductive stages (P treatment). Water stress (especially water stress at the reproductive cycle) interferes with pollination and results in an increased number of barren plants and incomplete seed setting (Teran and Singh 2002).

The VRP and RP treatments produced the maximum 1000-seed weights (no statistical difference), while the minimum 1000-seed weights were found at rain-fed treatment. In general, full irrigation (VRP) showed a greater efficacy than other treatments with respect to yield components.

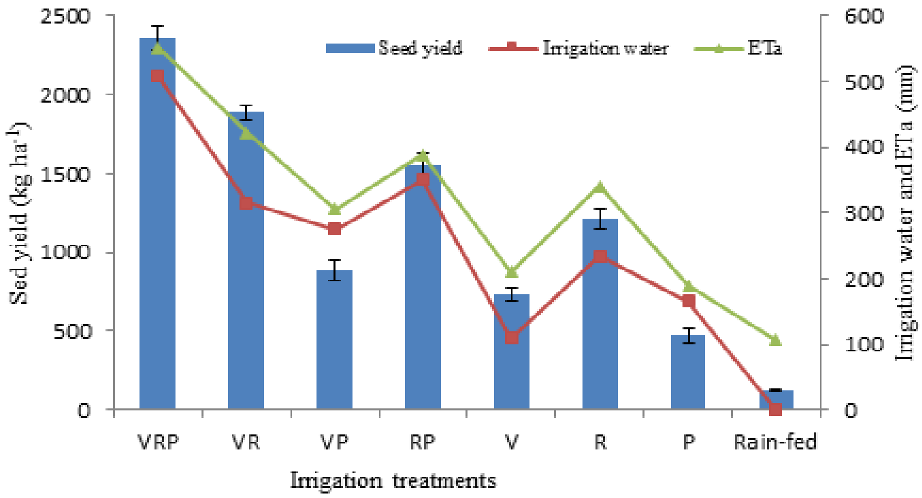

Figure 2
Seed yield, seasonal amount of irrigation water and ET_a in combined years (2013 and 2014) (Error bars represent the standard error values).

In this study, the WUE was higher in the VR treatment as 0.45 kg m^{-3} followed by the VRP treatment as 0.43 kg m^{-3} and the RP treatment as 0.40 kg m^{-3}. On the other hand, difference in the WUE value between these three treatments was not found statistically significant ($P\leq0.05$). The lower values of the WUE were obtained for the treatments involving the ignorance of irrigation at the reproductive cycle. The WUE values demonstrated between 0.3 and 0.6 kg m^{-3} by Doorenbos and Kassam (1979) and Mahlooji et al. (2000). Accordingly, our study maintained the WUE values in the common boundary as stated for dry bean by those researchers. Similarly, Miller et al (2002) cited a mean WUE of 0.29, varying between 0.03 and 0.67 kg m^{-3}, for dry bean among regions and years at the Northern Great Plains of the USA. The WUE depends on the plant growth cycle influenced by water deficiency level. For dry bean, the minimum WUE was addressed when water stress occurrance at the flowering and pod setting cycles (Calvache et al. 1997, Libardi et al. 1999, Pimentel et al. 1999).

On the other hand, the deficit irrigation strategies highly increased IWUE (Table 7). The highest IWUE values were obtained in V as 0.57 kg m^{-3}, VR as 0.56 kg m^{-3}, and R as 0.46 kg m^{-3} treatments and difference between these treatments was found no statistically significant in accordance of Duncan's multiple range tests. This result indicates the importance of both the vegetative and reproductive cycles in the programing of processing dry bean irrigation.

Yield Response Factor (k_y)

Average across both years, *ky* values were calculated for all growing period and individual growth periods

(Fig. 3). The seasonal *ky* value as known an important indicator in both irrigation and water deficit studies was estimated as an average of 1.19. Our seasonal *ky* value in line with the findings of Doorenbos and Kassam (1979) (*ky* = 1.15) and Sezen et al (2005) (*ky* = 1.23). The value of *ky* shows the crop sensitivity status of crops for the water stress environments i.e. lower than 1.00 generally means that the crop is tolerant to water deficit in the soil (Doorenbos and Kassam 1979). In accordance of *ky* value as 1.19 estimated from the current study, dry bean crop is sensitive to the water deficiency in soil. Many authors also reported that dry bean may strongly respond to water deficit (Munoz-Perea et al. 2006, Nunez-Barrios et al. 2005, Teran and Singh 2002, White et al. 1994, Ucar et al. 2009).

Except the VR treatment with *ky* = 0.87 in which irrigation water was not applied only at the pod filling-maturation stage, for all growth periods the *ky* value was greater than 1.00 (Fig. 3). Therefore, the bean plants could be considered as sensitive to water deficit in the vegetative and reproductive stages and tolerant to water stress condition in the pod filling-maturation period. In agreement with our findings, other researchers have also reported findings that such crop is more sensitive to water stress at the vegetative and flowering cycles (Efetha et al 2011, Munoz-Perea et al 2006, Nielsen and Nelson 1998). The maximum *ky* value was obtained in the VP treatment as *ky*=1.41 in which water was not practiced only at the timing of reproductive. The common bean cultivars respond differently to water stress in the soil during the reproductive period depending on the magnitude of the water stress (Karamanos and Papatheohari 1999, Schneider et al 1997, Teran and Singh 2002).

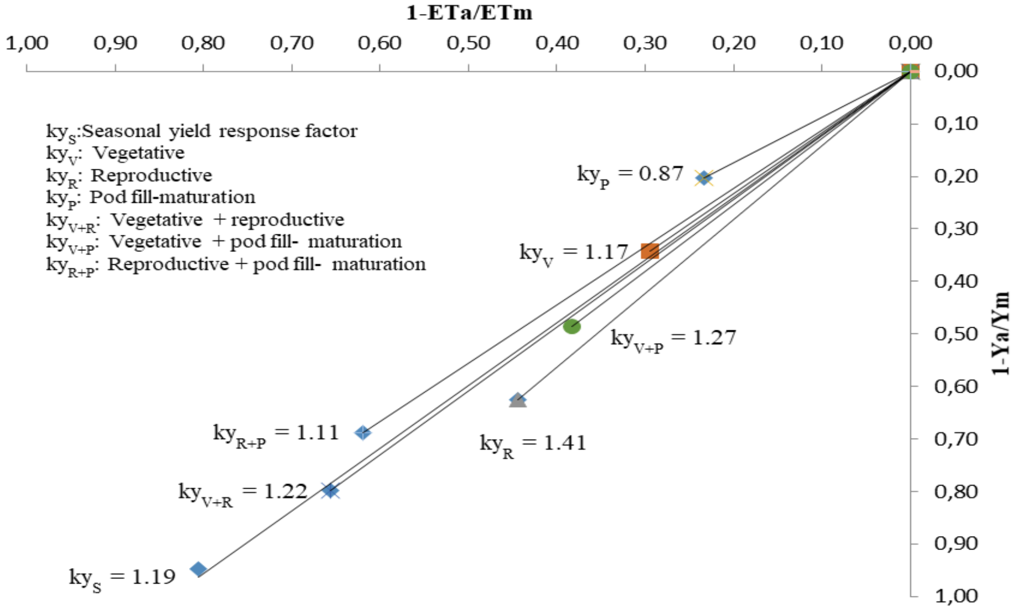

Figure 3

Yield response factors at various phonological stages of dry bean (in combined years)

4. Conclusions

In accordance of findings of two-year research, the maximum seed yield of 2362 kg ha^{-1} was obtained from well-watered treatment (VPR) across the years. Seed yield of dry bean was affected significantly from water stress timing (P<0.05). The data in the current work showed that reproductive period of dry bean was found the most sensitive time to water stress. Water deficiency at the reproductive cycle resulted low seed yield of dry bean approximately by 63% reduction by comparison to full-watered treatment. The finding explicitly indicated the resistance of dry bean to soil water deficiency at the pod filling-maturation stage when analyzed considering the seed yield, yield components, WUE, IWUE, and *ky*.

Proper information relevant to *Kc*, needed for irrigation management for regional scale, is unfortunately insufficient for many plants including dry bean in developing countries. Averaged over the years, for the vegetative, reproductive, and pod filling-maturation stages, the values of *Kc* were 0.75, 1.01, and 0.82, respectively. The mean *Kc* was estimated to be 0.85 for the whole season. Across both the years, the seasonal K_{pan} value was obtained as 0.89 during the growing season of dry bean. These values can be used in works relevant irrigation water management in arid and semi-arid environments where water resources are is scant.

As a conclusion, full irrigation treatment (VRP) is suggested for dry bean to achieve greater seed yields. On the other hand, in water shortage environments such as Konya region, practicing full irrigation up to the beginning of the pod filling-maturation cycle and stopping irrigation from that point up to harvest as an alternative to full irrigation at the all growing period resulted an economical seed yield. Based on the results of the current work, irrigation water saving of 38% and an increment of 27% in IWUE, by comparison to full irrigation, could be accomplished with this irrigation treatment. The ignorance of irrigation during the vegetative and especially the reproductive cycles is not desirable for an economical production of dry bean.

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The Incidence Rate of White Rot (*Sclerotinia sclerotiorum* (Lib.) de Bary) Disease in Sunflower Cultivation Areas in Konya and Aksaray Provinces and its Pathogenic Potential

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ABSTRACT

This study was conducted between June-September 2017-2018 in sunflower cultivation areas of Konya and Aksaray to determine the incidence rate of white rot disease and its pathogenic potential and to identify the disease agent *Sclerotinia* spp., Surveys were carried out 11,750 decares in total from Karatay, Altınekin, Cihanbeyli, Karapınar, Kadınhanı and Çumra districts of Konya province and 3000 decares in total from Centre of Aksaray (Hırkatol and Topakkaya village) and Eskil districts of Aksaray province. In the study, it was determined that the isolates obtained from diseased plants belong to *Sclerotinia sclerotiorum* (Lib.) de Bary. Although the disease was not seen in the first year in Konya, the disease rate in Altınekin district was determined as 9.38% in the second year. As a result of the survey studies, the disease rate in the Center of Aksaray in 2017 and 2018, respectively, was 2.83% and 3.97%; in Eskil, while no disease was occurred in the first year, it was determined at a rate of 4.16% in 2018. In the pathogenicity tests carried out with sunflower seedlings using approximately 20% of the isolates, it was found that the disease severity of the isolates varied between 56% and 66% and the difference between the disease severity and scale values of the isolates was statistically significant ($P < 0.05$). Aksaray / Hırkatol was found to be the most virulent isolate in the pathogenicity test.

1. Introduction

Sunflower (*Helianthus annuus L.*), which ranks fourth in the world and is one of the most important oil plants, is essential in terms of vegetable crude oil production due to the high oil content (22-50%) in its seed (Tekçe 2015).

It also ranks first in terms of cultivation area and production among the oilseed plants cultivated in our country. The highest amount of sunflower for oil is produced in the Thrace-Marmara Region (47.2%), followed by the Central Anatolia Region (29.2%). As a snack, it is mostly produced in the Central and Eastern Anatolia Regions (Anonymous 2016).

Many investigations are being carried out in order to expand the production areas of oilseed plants, which will be the raw material for vegetable oil production in Turkey. Accordingly, sunflower cultivation for oil is also encouraged in the irrigable areas of provinces in the inner parts of the Black Sea Region and provinces such as Konya and Aksaray in the Central Anatolia Region. Crop alternation of sunflower with sugar beet or wheat, especially in the Central Anatolia Region or its replacement in areas where sugar beet cultivation is restricted have contributed significantly to the increase in sunflower production for oil in our country (Onan et al. 1992; Öztürk et al. 2008).

According to 2017 statistics, in our country, 1 million 800 thousand tons of sunflower for oil was produced in 681 thousand hectares of cultivation area and approximately 10% of the cultivation area and the highest yield taken from the unit area is in Konya (Anonymous 2017). Sunflower consumes less water than sugar beet, corn and carrot plants, which have an important place in Konya's plant pattern. This is one of the reasons for the farmer to prefer sunflower and it is also a suitable plant for alternation with wheat (Yavuz 2016).

Sclerotinia species, one of the crown rot diseases in sunflower cultivation, cause significant losses (Benlioğlu et al. 2004; Kırbağ and Turan 2006; Yıldız et al. 2010; Koike et al. 2013). *Sclerotinia* diseases are defi-

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ned by different names such as cottony rot, white mold, watery soft rot, stem rot and head rot. The most important pathogen of our study, sunflower crown rot *Sclerotinia sclerotiorum* (Lib.) de Bary is a disease that is common in almost every region of the world where sunflower is produced, including our country. *S. sclerotiorum* is distributed in all regions with temperate, tropical or subtropical climates (Gulya et al. 1997). *Sclerotinia minor* Jagger is also another species that has been reported to cause root rot and wilting on sunflower, but it is much less common than *S. sclerotiorum*. The pathogen is a polyphagous and facultative parasite and is a host in more than 400 plant species belonging to 75 families (Lazar et al. 2011). *Sclerotinia sclerotiorum* can remain dormant with its sclerots in dry soil without hosts and causes early infections at the seedling stage (Khan 2007).

For the determination of *S. sclerotiorum*, which causes root and crown rot disease in sunflower in Turkey, Yucer (1980) conducted a study in the Thrace region, Çınar and Biçici (1982) in Çukurova, Cetinkaya and Yildiz (1988) in the Marmara region, Onan et al. (1992) in the Aegean Region, Tozlu and Demirci (2008) in the Pasinler Plain of Erzurum province and reported that it is an important disease of sunflower due to economic losses. Yield loss varies depending on the developmental period of the sunflower. Yield losses can reach 100% if the infection occurs at the early stage of sunflower development (Lamey et al. 2000; Saharan and Mehta 2008). Sunflower plants infected at the beginning of the flowering stage may lose 98% of their potential yield, while plants infected 8 weeks after flowering may lose only 12% of their potential yield (Maširević et al. 2006).

Since cultural measures and the use of resistance varieties are limited in the control against *S. sclerotiorum* in sunflower and the chemicals used have negative effects and are not economical, early diagnosis of the pathogen is very important in order to develop and increase disease control strategies (Kotan et al. 2009).

In Turkey, there are no studies conducted so far on the presence of fungal diseases that are among the agents that cause yield and quality losses in sunflower production areas in Konya and Aksaray provinces of the Central Anatolia region, which have a significant share in sunflower production. Therefore, this study aims to investigate *S. sclerotiorum*, which causes root and crown rot disease in sunflower production areas of Konya and Aksaray provinces of Central Anatolia Region. Although studies related to sunflower diseases in Turkey are limited in number, at least researching and analyzing the situation in the region will be of great importance in terms of providing important contributions to the literature as well as guiding and informing the producers of the region and the relevant organizations for the struggle.

2. Materials and Methods

2.1.Mateial

2.1.1.Test pathogen fungus

In our study, *Sclerotinia sclerotiorum* isolates obtained from diseased sunflower plants cultivated in Konya and Aksaray provinces were used as test pathogens. The isolates were grown on Potato Dextrose Agar (PDA) medium with streptomycin sulfate 0.9 g/L. Potato Dextrose Agar (PDA) is a general purpose nutrient medium used for the cultivation of a large number of fungi and yeasts. It was supplemented with acid or antibiotic (40 mg streptomycin sulfate / 100 ml) to inhibit bacterial growth. The nutrient medium was prepared as 4.0 g / lt Potato Extract, 20.0 g / lt Dextrose, 20.0 g / lt Agar and adjusted to pH 6.8 (Dhingra and Sinclair 1995).

2.1.2. Test plant

In the study, the sunflower plant was used as the host. When selecting the sunflower plant variety, the most cultivated varieties in the villages of Aksaray province, where *S. sclerotiorum* is common, were taken into consideration. Considering this, "İnegöl Alası", which is a sunflower variety for snack, was selected to be used in our study. The variety that has a wide cultivation area in the Aksaray region was obtained from the producers.

2.1.3.Cultivation environments used in pot experiments

In the pathogenicity test, sterile peat and perlite mixture at a ratio of 3: 1 in pots and 15-15-15 (N-P-K) commercial compound fertilizers were used for cultivation environments. The experiments were carried out with 2.5 lt (130 x180 mm) volume plastic pots.

2.2.Method

2.2.1.Disease survey

Sunflower cultivation areas in districts of Konya (Karatay, Altınekin, Cihanbeyli, Karapınar, Kadınhanı and Çumra) and Aksaray provinces (Center (Hırkatol and Topakkaya villages) and Eskil) were selected as survey areas. In the surveys conducted between June and September of 2017 and 2018, quite a lot of fields were examined and diseased and healthy plants were counted. The samples taken from the fields were examined as 20 plants per 1-5 da, 40 plants per 6-10 da, and 60 plants in fields larger than 10 da.

In order to determine the disease rates (%), at least 60 plants were selected from the areas selected from each province, in randomly determined rows, with approximately 10 plants each. Diseased and healthy sunflowers taken from different points of the field were counted, the results were converted into percentages and disease rates were calculated according to Bora and Karaca method (1970).

2.2.2.Isolation from diseased plants

Diseased plant samples collected from the study areas constituted the main material of the study. Depending on the number of diseased plants, 5-10 plants were sampled per field and used for isolation. After the plant samples brought to the laboratory to isolate the agent were washed in tap water, the pieces or sclerotiums taken were disinfected superficially in 1% sodium hypochlorite (NaOCl) for 1-2 minutes, then rinsed 3 times in sterile distilled water, and left to dry for 5 minutes on sterile blotting paper in a laminar flow cabinet. Then, each sample was planted in 2 petri dishes on Potato Dextrose Agar (PDA + Streptomycin sulphate) medium. 3-4 diseased tissue pieces were planted in each petri dish. These petri dishes were left to incubation at 20-25ºC and started to be monitored from the 2nd day. Pure cultures were obtained by transferring micellar discs of 5 mm diameter taken from the tip of colonies that developed from tissue pieces or sclerotiums within 2-3 days to petri dishes containing PDA. These *S. sclerotiorum* isolates were kept in a refrigerator at 10ºC and used in the next sta-ges of the study.

2.2.3.Identification of the isolates

It has been stated that it is possible to separate sclerotiums by size in order to define *S. sclerotiorum* and determine its differences from other species (Ekins et al 2005). The width and length of 5 sclerotium obtained from each isolate developed in PDA for 3 weeks were measured with a caliper and the arithmetic averages of the obtained values were taken (Lucas 1998).

2.2.4.Pathogenicity test

Pathogenicity was established with 4 repetitions according to the Random Parcel Trial Pattern and 2 (two) *S. sclerotinia* isolates obtained from sunflower fields in Aksaray province were applied to sunflower seedlings as a limited time stem inoculation method.

When the plants are in the R2 stage, which is the beginning of flowering (Nelson et al 1988), the mycelium discs of 4 mm diameter taken from the actively growing parts of the cultures of *S. sclerotiorum* developed in PDA for 7 days, were inoculated by placing a mycelium disc on each plant and into the wounds opened to the stem of the plant with a diameter of 5 mm, 4 cm above the soil surface, and wrapped with parafilm. The sterile PDA discs were placed in control plants. At the end of the incubation period (7 days), the length of light or dark brown lesions on the stem was measured from the point of inoculation with a digital caliper. 1-6 Root rot scale modified according to James (1971) (1: No symptoms in the plant, 2: Area with 1-10% necrosis, 3: Area with 10-25% necrosis, 4: Area with 25-50% necrosis. 5: Area with 50-75% necrosis, 6: Area with 75 -100% necrosis) was used and the disease severity (%) was calculated according to the Townsend-Heuberger (1943) formula.

The obtained data were analyzed with one-way ANOVA using the SPSS statistical program (SPSS Inc., version 17.0) and the significant differences between the averages were determined by Tukey multiple com-parison test (P≤0.05).

3. Results and Discussion

3.1.The results of disease survey

Sunflower production areas in Konya and Aksaray districts were continuously checked with an average interval of 20-30 days (30, 45, 60 and 90 days) starting from June (emergence) in 2017 and 2018. The results of the years surveyed in Konya are given in Table 1.

Table 1
Ratio (%) of White Rot Disease (*Sclerotinia sclerotiorum*) in Sunflower cultivation areas of Konya province

Years	Location	Production Area (da)	Number of fields surveyed	Survey area (da)	Number of diseased fields	Infestation % of field	Disease rate (%)
2017	Karatay	183710	25	1900	0	0	0
	Karapınar	96000	20	1000	0	0	0
	Cihanbeyli	83765	12	900	0	0	0
	Altınekin	79904	24	850	0	0	0
	Kadınhanı	78500	13	800	0	0	0
	Çumra	36670	14	400	0	0	0
2018	Karatay	204743	32	2100	0	0	0
	Karapınar	71523	13	700	0	0	0
	Altınekin	109002	28	1300	8	28	9,38
	Kadınhanı	76255	15	800	0	0	0
	Çumra	88722	16	900	0	0	0

While no plants showing symptoms such as root and crown rot, wilting, growth retardation, weak plant growth were occurred in 5,850 da area surveyed in 2017, abiotic related problems were observed more (Table 1). In 2018, *S. sclerotiorum* was detected in 4.74% of 5,900 da area, and abiotic related problems seen in the previous year were occurred again. Monthly (6th and 7th months) average relative humidity is 40.4% in Konya province while the average temperature is 24 ° C, and these climatic values are thought to prevent the emergence of the disease (*S. sclerotiorum*). Because the importance of humidity and precipitation in the development of the disease has been emphasized in many studies (Çetinkaya and Yıldız 1998; Huang et al. 1998; Matheron and Porchas 2000). Considering the average humidity, temperature and monthly precipitation data in Konya / Altınekin district, it is predicted that there are increasing values between 2017-2018 and that disease agents causing sunflower root rot may appear in this region in 2018. Considering these evaluations, a disease agent was encountered in the Oguzeli village of Altınekin during the 2018 surveys. As a result of the examination, 45 of 480 plants examined were found to be diseased and the disease rate was determined as 9.38%. In addition to climate data, faulty agricultural processes have triggered the emergence of disease. In particular, entering alternation for only 1 year, not leaving the field fallow and excessive irrigation are examples of these and also show that this disease may increase in the coming years. Among them, long-term crop rotation is very important in combating the pathogen (*S. sclerotiorum*) before it becomes a serious problem in a region (Rashid 2003).

The results of the surveys carried out in the sunflower fields of Aksaray province in 2017-2018 are given in Table 2.

Table 2
Ratio (%) of White Rot Disease (*Sclerotinia sclerotiorum*) in Sunflower cultivation areas of Aksaray province

Years	Location	Production Area (da)	Number of fields surveyed	Survey area (da)	Number of diseased fields	Infestation % of field	Disease rate (%)
2017	Merkez	49950	13	600	3	23	2,83
	Eskil	86500	20	900	0	0	0
2018	Merkez	64825	17	800	5	29	3,97
	Eskil	65066	18	700	4	22	4,16

The disease rate in the center was 2.83% in 2017, it was 3.97% in 2018. While no disease was occurred in Eskil in 2017, the disease rate was 4.16% in 2018 (Table 2). 23% of the survey area in the Aksaray region was infected with *S. sclerotiorum* in 2017. In 2018 surveys, it was observed that the disease occurred in districts where there was no disease in the previous year, and the rate of infection was between 22% and 29%. There may be different reasons for the emergence of the disease to increase compared to previous years or for the emergence of the disease in districts where it has never appeared. The disease started to appear in increasing density due to the fact that sunflower producers do not fully comply with the alternation in the production areas, successive sunflower cultivation is widespread, the time of cultivation is not appropriate, the cultivation is performed frequently, the diseased plant residues are not destroyed and the surface irrigation (wild irrigation) is applied. Crop rotation should be initiated before the pathogen becomes a serious problem in an area, and cultivating non-host crops for 3-5 years will reduce the number of sclerotia in the soil and minimize the impact of sunflower root infection (Gulya et al. 1997; Rashid 2003).

The fact that monthly (6th and 7th months) average relative humidity of Aksaray is quite high at 60% and the average temperature is around 21,6°C and lower than other provinces can be considered among the reasons why the disease is seen in this region. Sclerots from the previous year are the most important means of penetration and their germination is best performed at 24% soil moisture. However, destructive infections occur when sensitive plants are close (Irany et al. 2001; Lazar et al. 2011).

3.2.Isolation results and symptoms of the disease

When the sunflower fields were visited during the vegetation period, it was found that *Sclerotinia sclerotiorum* was the white rot agent of the disease which was obtained as a result of both macroscopic observations and isolations performed from diseased plants.

In the observations about the pathogen, it was seen that irregularly shaped light and dark brown lesions starting from the base of the sunflower stem and the expansion of these lesions in time led to the symptoms of cottony mycelium. The disease spreads completely by covering the stem. The most obvious and typical symptom of the pathogen is the formation of amorphous sclerotium on the infected sunflower stem, which are initially white but then turn black on the outside and begin to harden. Over time, the stem of the infected plant can be broken easily by taking a thready appearance, and sclerotiums are seen to form when these parts are opened. Similar symptoms were observed in a survey carried out on sunflower in Pasinler plain of Erzurum and 169 *S. sclerotiorum* isolates were obtained in isolation from roots (Tozlu 2003).

S. sclerotiorum was found in only 1 locality in Konya and 3 different localities in Aksaray. As a result of a 2-year survey study, 2 isolates from Aksaray Province Center (Topakkaya village) in 2017, 4 isolates from Aksaray Province Center (Hırkatol village), 3 isolates from Eskil (Kökez village), 1 isolate from Konya province Altınekin (Oguzeli village) was obtained. Thus, a total of 10 isolates were determined.

3.3.Identification of isolates

The agents of white rot disease are *S. sclerotiorum and S. minor*, and the distinction of these two species is based on the size of the sclerotium. S. *minor* forms more, small, irregular sclerots. It was determined that all isolates belong to *S. sclerotiorum* by the measurements of sclerot sizes of the isolates obtained as a result of the isolations. When all localities are considered in general, the length of the sclerots varies between 4.4-8.19 mm (5.8 mm) and the width is between 2.13 and 5.9 mm (4.0 mm). The results in this study are in accordance with the sclerots of *S. sclerotiorum* in the literature with sizes ranging from 5-20 mm (Singleton 1992) and 3-10 mm (Ekins et al. 2005).

3.4.Pathogenicity test of isolates

In pathogenicity tests, Aksaray (Eskil and Hırkatol) isolates obtained from the regions where the disease occurred for two consecutive years were used and it was found that the scale values of the isolates varied between 5-6. As a result of the pathogenicity tests, a difference was observed between the lesion lengths of the symptoms (Table 3). When the lesion lengths of the repetitions were evaluated in general, Hırkatol isolate was measured as the highest 12 cm and the lowest 10 cm, and the Eskil (Kökez) isolate as the highest 9.5 cm and the lowest 5.5 cm. It was observed that this difference is related to the humidity and precipitation during the vegetation period, which was supported by the studies (Minkevich and Kosorukova 1987; Tozlu 2003; Onaran 2009). Both isolates were observed to cause complete death in plants and are highly virulent. Differences in virulence among the isolates of *S. sclerotiorum* have been revealed by many researchers (Marciano et al. 1983; Kohn et al. 1990).

Table 3
Disease severity rate (%) of *Sclerotinia sclerotiorum* isolates

Isolates	Average lesion lengths (cm)	Disease severity (%)
Aksaray/Hırkatol	11 a	66 a
Aksaray/Eskil (Kökez)	7.5 b	56 b

* There is no statistical difference between groups bearing the same letters (P <0.05)

One of the most important reasons why the disease severity occurs most in the isolate taken from Hırkatol is thought to be caused by the continuous cultivation of the same product due to the intensive sunflower cultivation in this region. In many studies, the reason for the high inoculum density has been reported to be due to the continuous cultivation of the same crop in the same fields and continuous precipitation (Morton and Hall 1989; Dorrance and Lipps 2002).

4. Conclusion

In the study, it was determined that the agent that causes white rot disease in sunflower cultivation areas in Konya and Aksaray provinces is a fungal agent named *S. sclerotiorum*. Determining the disease in sunflower is important since no detailed studies have been carried out in these regions before.

In the study, it was aimed to determine the prevalence rates of *S. sclerotiorum* and it was observed that the disease appeared at increasing rates in the districts of Aksaray every year and the average disease rate for two years was found to be 3.5%. As a matter of fact, in studies conducted on sunflower in our country, it has been stated that the prevalence of *S. sclerotiorum* varies between 2.5-100% (Onan et al. 1992; Demirci and Kordalı 1998; Tozlu 2003).

In Konya province, the course of the disease, which was observed only in the second year, was quite high with a rate of 9.38%. Altınekin District Directorate of Agriculture and the producers stated that the disease was seen several times in previous years. Considering the temperature and humidity values of 2017, it is thought that the emergence of the disease may increase in the following years. In addition, it can be said that the amount of inoculum will increase over the years depending on sunflower production and even this disease will cause an epidemic by posing a potential danger. It is thought that detecting the areas where *S. sclerotiorum* may occur and diagnosing the disease will contribute greatly to combat this pathogen and reduce its inoculum potential.

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Population Development and Infestation Rate of Codling Moth (*Cydia Pomonella* (Lepidoptera: Tortricidae)) In Apple Orchards in Northern Kyrgyzstan**

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ABSTRACT

The codling moth is a key and most widely distributed pest of apple orchards worldwide. The population development of *C. pomonella* was investigated using sex pheromone traps in different apple orchards between years of 2019 and 2020 in northern Kyrgyzstan. Flight of the codling moth males in apple orchards is characterized by instability, which is associated with temperature and other climatic factors. Trap captures of codling moth were positively correlated with temperature, but negatively correlated with relative humidity and altitude. Male moths started appearing in traps on April 10-14, 2019 and April 26-29, 2020 in Chui and Ysyk-Kol provinces. Analysis of seasonal trap catches from apple orchards over two years summarizes that the codling moth has 4 major peaks in Chui and 3 distinct peaks in Ysyk-Kol provinces. Codling moth damage per orchard ranged from 8.3% to 84.3% in Chui province and it was estimated per orchard from 1.4% to 27.2% in Ysyk-Kol province.

1. Introduction

Apple is one of the most widely produced and economically important fruit crops in temperate regions around the world. Cultivated apple (*Malus domestica* Borkh.), which is the oldest fruit crop used as a cultivated plant, has been domesticated from *Malus sieversii* in the Tian Shan Mountains for 4000–10,000 years and dispersed from Central Asia to West Europe along the Silk Road (Cornille et al. 2014; Duan et al. 2017). Since the homeland of the apple is Central Asia, it has been reported by the researchers that some pests and diseases of apple trees are unique to Central Asia, and it is still the subject of great interest for research (Luby et al. 2001; Mills 2005).

Codling moth, *Cydia pomonella* L. (Lepidoptera: Tortricidae), originated from Central Asia is a key and most widely distributed pest of apple orchards worldwide (Barnes 1991; Mills 2005). Its host range is restricted mainly on apple, pear, crabapple, quince, hawthorn, and walnut, with one to four generations a year in the palearctic zone (Johnson 2013). Codling moth adult females lay eggs on the fruit or leaf surface, hatched larvae mostly bore directly into the fruits and eats the seeds inside the fruits. There are five larval instars, at maturity, larvae usually leave the fruits and usually pupate under the bark. Codling moth overwinters as mature diapausing larvae in cocoons until climatic conditions are suitable for adults to fly (Welter 2009).

Pest monitoring is a fundamental component of IPM programs and sex pheromones are the best tools to monitor the seasonal flight periods of pests, and they are widely used in a variety of ways in pest control programs in agricultural crops (Fadamiro 2004). Sex pheromones are nontoxic and species-specific blends, which produced by adult females in order to attract males for mating (Baker and Heath 2005). Captures in traps baited with synthetic pheromone lures accurately show whether a specific insect is present, provide reliable information about seasonal activity of pests and effective time of insecticide sprays (Witzgall 2010). Numerous studies were conducted to determine the population development and infestation rate of *C. pomonella* in the different region of the world using sexual pheromones (Fadamiro 2004; Mamay and Yanık 2013; Zada et al. 2014; Aydoğan and Ünlü 2019)

In Kyrgyzstan, apple production is small (135 ths tons/year) and unstable due to yield and quality loss from key pests and diseases. Although *C. pomonella* is considered to be a key pest, no scientific studies have been conducted on this pest last 30 years and the present situation of the pest in the region is not known clearly. Studies conducted earlier than 1990 or during

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USSR time have mainly focused on determining the pest population with the help sum of effective temperatures or light traps (Vasilev and Pristavko 1970; Mamaev 1981). According to the information we obtained from the literature we could reach; the pest population development was not determined using sex pheromones at least in Kyrgyzstan. Consequently, there lack effective pest management programs against this pest for growers, and efforts to control the codling moth relies mostly intensive use of broad-spectrum insecticide sprays throughout the growing season, which has resulted in the development of insecticide resistance, and an increase in the abundance of secondary pests (Vreysen et al. 2010).

The aim of this study was: (1) to monitor population development, and (2) to estimate the damage of codling moth in apple-growing regions of northern Kyrgyzstan. We consider flight pattern information of pest and other observations obtained through this study will be useful in determining the control methods against this pest.

2. Materials and Methods

Population development

This study was conducted from April 2019 to October 2020 in three apple orchards in Chui province, and five in Ysyk-Kol province (YK), North Kyrgyzstan. Orchards' main characteristics and pest control informations are given in Table 1. Populations of adult codling moths were determined from the catches of male moths using delta-type pheromone traps for two years. In all traps, sticky trays were used for catching and counting, and species-specific pheromone capsules, which contain 1,5 mg E.E-8.10-dodecadien-1-ol, also known as codlemone (Russell IPM Ltd., Deeside, Flintshire, UK) used to attracting codling moth males to the traps. The traps were hung at 1.5-2 m high from the ground in the south direction of the trees and in the direction of the dominant wind. Trap visits were performed every day of week until the first adult was captured, and once a week after the first adult was captured, the number of captured adults were recorded. The pheromone capsules of the traps were replaced every six weeks and old capsules were removed from the orchards. The sticky trays in the traps were replaced with new ones as needed depending on the loss of the adhesive layer (Knight et al. 2009; Çelik and Ünlü 2017).

Infestation rate and data analysis

To estimate the level of infestation, the damage to fruits caused by the codling moth was surveyed in July and September, in two consecutive years (2019, year 1; 2020, year 2). Different sampling methods can be used to determine the infestation rate of *C. pomonella*. Three different methods; 'Tree-Based', 'Fruit-Based' and 'Crate-Based', are commonly used to determine the codling moth infestation rates (Mamay and Yanık 2013). In this study 'Fruit-Based' method was used to determine the infestation rate of the pest. In total, approximately 100 fruits were randomly collected from 5 trees in the center of each orchard each time and holes of codling moth larvae were determined from visual examination of each apple in a sample. Only apples that attached to the tree were assessed for larval infestation. The level of infestation (%) was calculated by the equation:

Level of Infestation (%) = (Ni / Nc) x 100

where Ni is the number of damaged fruits and Nc is the number of collected fruits in orchard.

Table 1
Location, main characteristics and pest control information's of apple orchards.

Name of orchard	Lat (°N)	Lon (°E)	Al (m)	Size (ha)	Age of trees (y.old)	Varieties	Insecticide application
2019							
Chui-1	42˚54'16''	74˚48'21''	731	0.7	12-15	Semerenko, Pre, R.d, G, İdared	(1) imidacloprid; (2) lambda-cyhalothrin
Chui-2	42˚49'12''	74˚38'21''	878	1.5	20-25	Aport, Pre, K.z	No ins. application
Chui-3	42˚55'53''	74˚49'42''	1313	5	35-40	Aport, Pre, K.z	No ins. application
YK-1	42˚10'02''	77˚37'02''	1696	0.5	15-20	Makintosh, K.z, Pre	thiacloprid
YK-2	42˚18'27''	77˚52'57''	1733	1.5	25-30	Pre, Aport	thiacloprid
YK-3	42˚25'43''	78˚12'11''	1760	1	20-25	Pre, Aport, K.z	dimethoate
YK-4	42˚46'24''	77˚43'57''	1780	0.6	25-30	Zolotoy Ranet, Pre, Aport	No ins. application
YK-5	42˚45'10''	77˚39'26''	1688	3	4	İ, Pre, G, Krimson	No ins. application
2020							
Chui-2	42˚49'12''	74˚38'21''	878	1.5	20-25	Aport, Pre, K.z	No ins. application
Chui-3	42˚55'53''	74˚49'42''	1313	5	35-40	Aport, Pre, K.z	No ins. application
YK-2	42˚18'27''	77˚52'57''	1733	1.5	25-30	Pre, Aport	lambda-cyhalothrin

Pre: Prevoshod, R.d: Red Delicious, G: Golden, I: Idared, K.z: Kirgizskiy Zimniy

Statistical analysis was conducted using SPSS v.22.0 (IBM, Armonk, NY, USA). The significance of altitude on the number of male catches in monitoring traps was determined by correlation (Pearson) and regression analysis at $P = 0.05$ for the multiple comparisons. The relationship between temperature with codling moth catches was evaluated using linear multiple regression analysis. T-test was used to compare the damage rates of apple orchards according to years, and Kruskal-Wallis Test was conducted to examine the differences of damage rates between orchards and provinces.

3. Results and Discussion

Population development

Pheromone traps were installed at apple orchards and used to monitor *C. pomonella* populations in Chui and Ysyk-Kol provinces from April to October in 2019 (24 traps) and 2020 (9 traps) (Fig. 1; Fig. 2). Results from two-year study showed the detection of four major peaks (late April - early May, late May – early June, late June – early July, and early August – mid August) and three distinct peaks (late May – early June, late June – early July and late July – early August) of the pest in Chui and Ysyk-Kol provinces, respectively.

Chui province. In 2019, the first codling moth catch in Chui-1, Chui-2 and Chui-3 orchards were April 11th, April 13th, and April 14th, respectively. But, in 2020, moths started appearing in traps a week later than 2019, on April 21 and April 20 in Chui-2 and Chui-3 orchards, respectively. In Chui-1 orchard, a total of 259±12.6 (Mean±SE) males were caught in pheromone traps in 2019, with four peaks on April 14, May 15, June 19, and July 31 (Fig 1; Fig 2; Table 2). In 2020, monitoring has not carried out in this orchard due to regularly visiting problems. The total captured adult male moths' number were 1089±119.8 and 779±31.39 in Chui-2 orchard, in 2019 and 2020, respectively. According to trap data, four major peaks of the population were established in Chui-2 orchard, on May 5th, May 29th, June 22 and July 31 in 2019 and May 12, June 16, July 21, August 18 in 2020 (Fig 1; Fig 2; Table 2). The Chui-3 orchard has the highest pest population among all orchards, with four peaks on May 8, June 5, July 10 and August 14 in 2019 and May 12, June 23, July 28, and August 25 in 2020 (Fig 1; Fig 2; Table 2). The total captured moths were 1287±99.3 and 823±36.7 in 2019 and 2020, respectively.

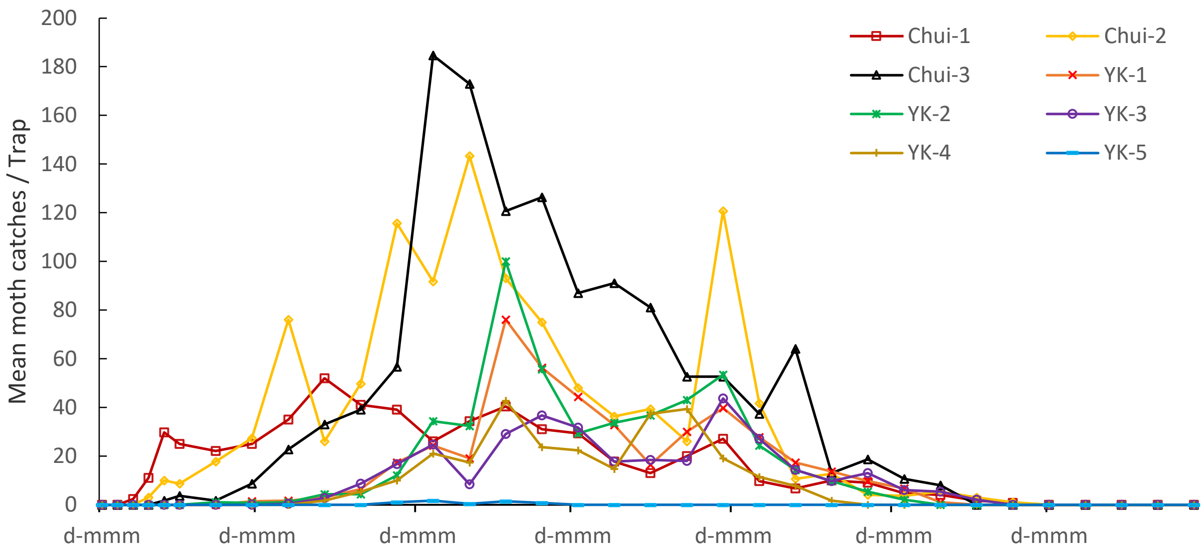

Figure 1
Population development of *Cydia pomonella* in apple orchards in Chui and Ysyk-Kol provinces in 2019. Each observation represents a mean of three replications.

Ysyk-Kol province. In 2019, population of codling moth monitored at 5 different orchard, and pest flight pattern was nearly similar in all orchards. The first codling moth catch in traps in YK-1, YK-2, YK-3, and YK-4 orchards were May 3, April 26, May 14, and May 18, respectively (Fig 1). The total captured adult male moths' number in YK-1, YK-2, YK-3, and YK-4 orchards were 444±36.7, 497±45.4, 333±18.2, and 275±15.9. In 2019, adults of codling moth were caught with the main and first peak on late of May and then undergone two more generations (late June – early July and late July – early August) in YK-1, YK-2, YK-3, and YK-4 orchards in Ysyk-Kol province (Fig 1; Table 2). In YK-5 orchard, a total of only 15 male codling moths were caught in three pheromone traps, starting from May 31 till June 22. The reason for this low population probably is due to the age of this orchard. In 2020, population monitoring was carried out in only one orchard (YK-2), because of codling moth flight pattern similarity in 2019 and regularly visiting problems due to global pandemic condition. Codling moth appeared from April 29 and showed three peaks until late August.

According to results, trap captures were positively correlated with temperature (r = 0.550; P = 0.001 in Chui and r = 0.558; P = 0.001 in Ysyk-Kol in 2019; r = 0.480; P = 0.001 in Chui and r = 0.228; P = 0.001 in Ysyk-Kol in 2020) and negatively correlated with relative humidity (r = -0.282; P = 0.001 in Chui and r = -0.359; P = 0.001 in Ysyk-Kol in 2019; r = - 0.270; P = 0.001 in Chui and r = - 0.288; P = 0.001 in Ysyk-Kol in 2020). Temperature data are given in Fig 3.

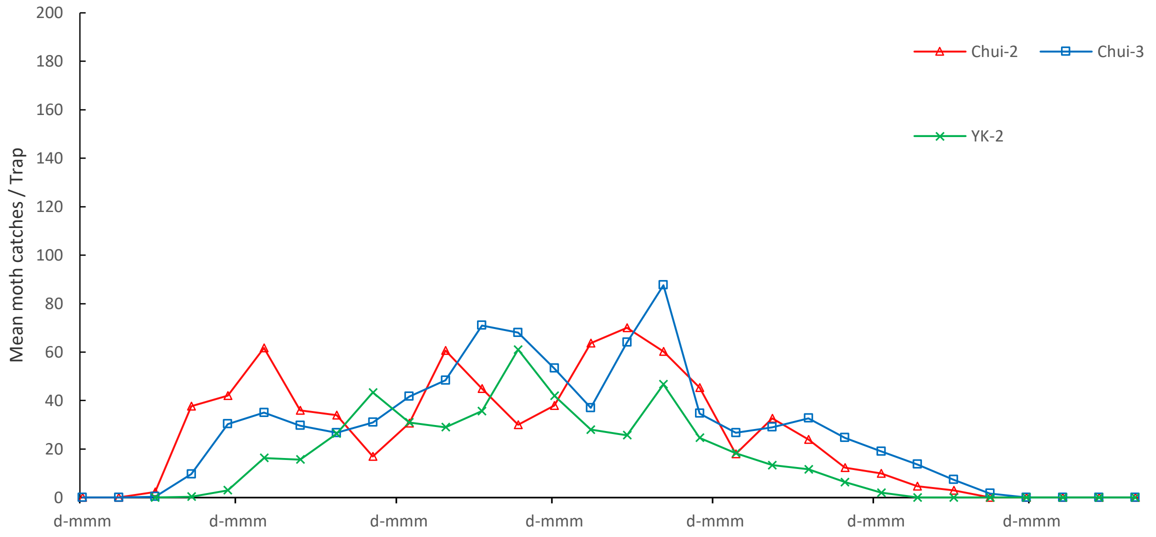

Figure 2

Population development of *Cydia pomonella* in apple orchards in Chui and Ysyk-Kol provinces in 2020. Each observation represents a mean of three replications.

Table 2.
Population events (Mean±SD) of codling moth in apple orchards in Chui and Ysyk-Kol in 2019 and 2020.

Province	Orchard	Year	1st catch	1st peak	2nd peak	3rd peak	4th peak
Chui	Chui-1	2019	3.33±1.52	25.6±3.18	40.3±8.74	20±2.4	10.5±6.92
		2020	-	-	-	-	-
	Chui-2	2019	10±4.32	27.3±2.86	115.7±29.4	75±16.8	62.7±13.9
		2020	2.33±1.15	61.7±22±85	60.7±19.01	63.7±14.9	32.7±8.96
	Chui-3	2019	1.95±3.01	13.93±13.44	184.7±6.18	91±7.88	64.5±12.4
		2020	9.7±5.03	35±6	41.7±10.7	71±12.49	87.7±12.42
Ysyk-Kol	YK-1	2019	1.33±1.24	24.3±10.8	76±26.05	39.6±7.09	-
		2020	-	-	-	-	-
	YK-2	2019	4.3±3.24	34.3±5.50	100±7.93	53.3±13.61	-
		2020	3±1.73	43.4±7.09	61±11.1	46.7±10.1	-
	YK-3	2019	2.66±1.52	24.66±7.50	36.6±4.93	43.7±7.37	-
		2020	-	-	-	-	-
	YK-4	2019	5.33±3.05	21±10.44	42.7±13.31	39.3±4.16	-
		2020	-	-	-	-	-
	YK-5	2019	0.7±1.15	1.7±1.15	-	-	-
		2020	-	-	-	-	-

Correlation studies revealed that codling moth adult catches had negative correlation with altitude in all orchards (r = -0.571; *P* = 0.013). The overall regression analysis was statistically significant (F=7.34, $p<0.006$, $R^2=0.50$). Detailed regression values are given in Table 3.

Infestation rate

Codling moth damage to apples was not significantly different between years (*df=26; t=-3.19; p = 0.531*), but it did vary significantly between orchards (*df=6; chi-square=18.488; p=0.005*) and provinces (*df=1; chi-square=7.350; p=0.007*) each year (Table 4). In Chui Province, CM damage per orchard ranged from 8.3% to 84.3% and from 15.4% to 77.1% in 2019 and 2020, respectively. But, in Ysyk-Kol province it was estimated per orchard from 1.4% to 20.6% and from 5.3% to 27.2% in 2019 and 2020, respectively. Damage, in general, was greater in Chui province (47.03%±26.01; mean ± SD) than in Ysyk-Kol (14.08%±8.64). Moreover, damage was higher in 2020 (31.15%±22.25; mean ± SD) than in 2019 (25.23%±26.75).

The most widespread and ubiquitous use of sex pheromones has been detection and population monitoring. In pest management programs, population monitoring using sex pheromone is necessary to determine thresholds, to schedule insect control applications on time (Baker and Heath 2005). In this study, we monitored seasonal flight patterns of *C. pomonella* and estimated its damage status in apple orchards in northern Kyrgyzstan.

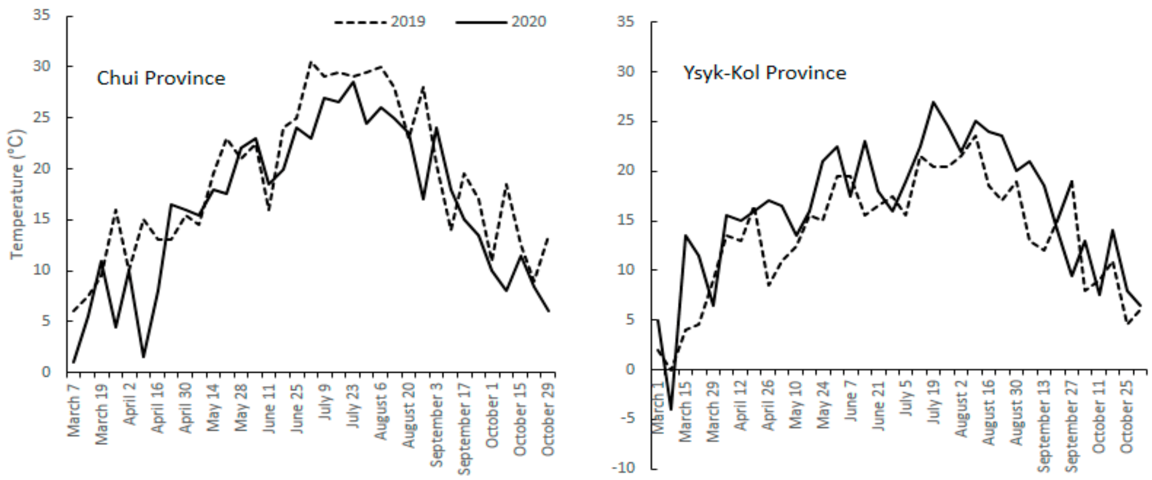

Figure 3
Temperature data of Chui and Ysyk-Kol from Bishkek and Cholpon-Ata Meteorological Station, 2019 and 2020.

Our data on seasonal abundance indicated that the flight of the codling moth males in apple orchards is characterized by instability, which is associated with temperature and other climatic factors. Trap capture results showed 3-4 and 2-3 peaks of codling moth in Chui and Ysyk-Kol provinces. Thus, based on the above material, it can be noted that the codling moth developed in three and two generations in a year in Chui and Ysyk-Kol provinces, respectively. Similar results noted by Konurova et al. (2017) that codling moth able to develop three generations in Chui valley. Numerous reports have been published (Riedl and Croft 1978; Blomefield et al. 1997; Reuveny and Cohen 2004; Aydoğan and Ünlü 2019) dealing with codling population under similar climate with Kyrgyzstan, which shows codling moth is essentially bivoltine with considerable yearly variability in third generation emergence. That the very low number of male codling moths caught in traps at YK-5, compared to the other orchards, is likely an indicator that the population of codling moth is not settled yet due to age of trees.

Table 3
Comparison of total mean moth catches of *Cydia pomonella* at different altitude using delta pheromone traps during 2019 and 2020.

Site / Year	Altitude (m a.s.l)	N	Monitoring Period	Total captured males (Mean ± SE)	Anova
Chui-2 / 19	878	3	March - November	1089.3±119.9	F=5.69, p<.048, R^2=.049
Chui-2 / 20	878	3	March - November	779±31.3	F=8.16, p<.024, R^2=.054
Chui-3 / 19	1313	3	March - November	1287.6±99.3	F=5.69, p<.048, R^2=.049
Chui-3 / 20	1313	3	March - November	823±36.6	F=8.16, p<.024, R^2=.054
YK-2 / 19	1733	3	April - November	497.3±45.4	F=5.69, p<.048, R^2=.049
YK-2 / 20	1733	3	April - November	535±35.3	F=8.16, p<.024, R^2=.054

N: number of replications

Some factors such as photoperiod and temperature are known to play a key role in codling moths' seasonal activity (Setyobudi, 1989). In our study, trap captures of codling moth were positively correlated with temperature, but negatively correlated with relative humidity and altitude. This is in agreement with Pitcairn et al. (1990) and Zada et al. (2014), who reported weather parameters on codling moth population dynamics, but, in addition to other studies, here we investigated also the effect of altitude on the population.

Our study also points that the codling moth damage in orchards ranged from 1.4% to 84.3%, mostly it was around 15-25% at harvest time which show extremely high loss of yield. We consider, this high damage correlated with insufficient control against codling moth and other pests. As determined in the study, growers have applied only once or twice a year insecticide in their orchards. Here, we suggest that biological control or other environmentally friendly methods such as mating disruption or microbial control immediately should be implemented in apple orchards by growers, because only 1-3% of infestation by codling moth may tolerable in intensive production (Pajač et al. 2011).

Our results clearly showed the population fluctuation of the *C. pomonella* throughout the season in Kyrgyzstan and also give about the right time for spray application for the effective management of this pest. Successful future management of codling moth will require detailed researches using other models, such as degree day model (DD). Because, the DD model is also used to assess phenology and seasonal occurrence of the *C. pomonella* effectively.

Table 4
Infestation rate of codling moth in apple orchards in North Kyrgyzstan.

Sampling Site	Infestation rate (%)			
	mid-July 2019	mid-September 2019	mid-July 2020	mid-September 2020
Chui-1	8,30	22,30	15,40	27,30
Chui-2	52,60	84,30	61,10	77,10
Chui-3	36,70	73,20	36,20	69,50
YK-1	7,90	15,10	14,10	25,10
YK-2	3,10	20,60	25,20	27,20
YK-3	1,40	16,40	5,30	23,10
YK-4	3,50	7,85	11,20	18,20

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Early Detection of Mastitis by Using Infrared Thermography in Holstein-Friesian Dairy Cows Via Classification and Regression Tree (CART) Analysis

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ABSTRACT

Subclinical mastitis is an important udder disease that negatively affects both the animal health and reduces profitability in dairy farms. The increasing performance of thermal cameras over time and their usability in different areas increase their use in livestocks. Infrared thermography (IRT) technology is a noninvasive method that can estimate the surface temperature of objects. The objective of this study was to evaluate early detection of mastitis in Holstein-Friesian dairy cattle by using both udder surface temperatures (Tmax) from images obtained with the help of a FLIR One Pro thermal camera and some parameters such as Lab (CIE L*, a*, b*), HSB (Hue, Saturation, Brightness), RGB (Red, Green, Blue) by processing thermal images with the help of ImageJ program via classification and regression tree (CART) analysis. According to California Mastitis Test CMT by using CART analysis in this study, 64.9% of cows with udder surface temperature lower than 38.85 were healthy, and 73.3% of cows higher than 38.85 were determined as unhealthy. As for SCC, 77.6% of cows with udder surface temperature lower than 38.65 were healthy and 58.6% of cows with higher than 38.65 were determined as unhealthy. The areas under ROC (AUC) were found to be statistically significant in the diagnosis of subclinical mastitis. ($P<0.01$) The sensitivity and specificity of the CART algorithm for CMT and SCC diagnostic tests were 85.42%, 81.48% and 90.20%, 80.39%, respectively. There was no significant difference between SHS and CMT tests in the area under the ROC curve ($P>0.05$). As a result, IRT technology can be used as a useful diagnostic tool in the early detection of mastitis.

1. Introduction

Inadequate and unbalanced nutrition is one of the major problems for humanity. With an essential role in healthy and balanced nutrition, milk is a unique nutrient at every stage of human life. The quality of milk required for food safety is linked to udder health in cows. For this reason, the first production step plays a key role for healthy milk (Aytekin et al 2018). Mastitis is considered as an economically important udder disease, especially in its subclinical form (Kaşıkçı et al 2012). Miller et al. (1993) stated that in dairy cattle it results in severe economic losses from reduced milk production, treatment cost, increased labor, milk withheld following treatment and premature culling (Sharif et al 2009). Wide variation in the mastitis in a herd is attributable to genetic (herd, breed etc.) and non-genetic factors (parity, season, age, calving month, calving year, lactation stage etc.). Also, udder and teat morphology can also affect the mastitis level of the dairy cows (Uzmay et al 2003). Morover, cow cleanliness is important for providing hygienic milk production and the welfare of dairy cows (Aytekin et al 2021).

Monitoring of mastitis program is important for the udder health status of the herd and the quality of the raw milk in the herd. Monitoring udder health and milk quality can be routinely determined by evaluating the somatic cell count (SCC). The somatic cell count of uninfected mammary glands should be less than 200,000 cells/mL (Schukken et al 2003). In addition, the california mastitis test (CMT), which subjectively estimates the somatic cell number indirectly, is widely used in enterprises. CMT solution forms a gel by breaking down the cell membrane of leukocytes or epithelial cells in the milk sample and allowing the DNA to react with the test reagent. The higher the number of nucleated cells in the milk, the higher the gelation rate (Koçyiğit et al 2016). In addition to these methods, several different analytical methods such as White Side Test (WST), Catalase Test, Wisconsin Mastitis Test (WMT), breed method, coultercounter, DNA filter method and integrated fluorescent microscope methods have been used, as well as electrical conductivity, milk color sensor devices and biochemical analysis (Baştan et al. 1997; Yağcı 2008; Kaşıkçı et

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al. 2012; Aytekin and Boztepe 2013; Aytekin et al. 2018). In short, early diagnosis of mastitis is very important in terms of minimizing economic losses in enterprises, protecting the welfare of animals and producing quality milk. Infrared thermography (IRT) is an important and noninvasive method that can estimate the skin surface temperature of examining physiological changes and responses (Hovinen et al. 2008; Jones and Plassmann 2002; Byrne et al. 2018).

Thermal cameras first started to be used in military areas and later became widespread in industrial areas (Polat et al. 2010). Recently, IRT has been used frequently for early diagnosis of some diseases such as mastitis (Bitman et al. 1984; Porcıonata et al. 2009; Polat et al. 2010; Sathiyabarayhi et al. 2016 and Golzarian et al. 2017), lameness (Eddy et al. 2001; Alsaaod et al. 2012; Stokes et al. 2012; Gianesella et al. 2018; Fabbri et al. 2020), östrus detection (Hurnik et al. 1985; Talukder et al. 2014; Marquez et al. 2019), sperm quality (Menegassi at al. 2015), pregnancy (Jones at al. 2005; Bowers et al. 2009; Radigonda et al. 2017), heat stress (Daltro et al. 2017; Unruh at al. 2017), prediction of live weight (Stajnko et al. 2008; Stanjko et al. 2010; Kuzuhara et al. 2015), measurement of body temperature (Cangar et al. 2008; Nascimento et al. 2011), milking machine performance (Castro-Costa et al. 2014; Tangorra et al. 2019), animal welfare (Stewart et al. 2005; Abudabos et al. 2013), in the livestocks. Furthermore, its small size provides portability and ease of use, while being able to use the image remotely without physical contact with the animal provides great convenience as a safe evaluation method and detecting diseases in the livestocks (Fabbri et al. 2020). First of all, the main advantages of the thermal camera are that it is a remote, non-contact and non-invasive method, absolutely painless, fast and reliable, a real time technique, enable monitoring of dynamical variations of temperature and also has no harmful radiation effects (Lahiri et al. 2012). Moreover, in thermal imaging, the hottest areas appear red or white color, while the coldest areas appear blue or black color (Colak et al. 2008; Polat et al. 2010; Sathiyabarathi et al. 2016).

CART is a non-parametric method that analysis complex relations between dependent and independent variables with group effects by classifying the sample into homogenous sub-groups and entering the model (Kayri and Boysan 2008). Classification and regression tree (CART) practiced for nominal, ordinal, and continuous variables is one of the data-mining algorithm used for constructing the decision tree (Çelik et al. 2016). Furthermore, CART has an advantage is that the analysis technique is free from the presumptions of multiple regression analysis such as normality, homogeneity, and interdependency of observations for parametric methods are ignored (Kayri and Boysan 2008).

The objective of thepresent study is to evaluate the potential benefit ofthe thermal camera as a noninvasive tool by CART analysis in the early detection of mastitis in Holstein-Friesian dairy cattle.

2. Materials and Methods

Animals and Milking managements

The animal material of this study consisted of Holstein-Friesian dairy cows reared in a private dairy cattle farm in Karapınar district of Konya province. Dairy cows were fed ad libitum with TMR containing a mixture of concentrated feed and forage such as straw, alfalfa, fescue grass, corn silage and alfalfa silage. Milking was carried out 3 times a day by two milkers in the enterprise. Milking management and hygiene rules were implemented in the enterprise. Dairy cows milked three times daily in a 2 x 15 parallel milking parlour with EcoHerd management program. Milk sampling, udder photography and animal breeding practices were performed according to the animal welfare rules stated in Article 9 in government law in Turkey (No. 5996).

Milk sampling

Milk samples of 102 head primiparous Holstein-Friesian dairy cows were taken by using sampling equipment during milking time in order to represent homogeneous of all milk. The milk samples were cooled immediately and transported in cooler boxes to the Animal Biotechnology laboratory of the Department of Animal Science within 2 h. California Mastitis Test (CMT) and Somatic Cell Count (SCC) were determined from milk samples taken into falcone tubes (50 mL) in the morning milking.

Somatic Cell Count (SCC) and Electrical Conductivity (EC)

Somatic Cell Counts SCC (cell/ml) from milk samples were measured using NucleoCounter SCC-100 (Chemometec, Denmark). The numbers of cells/ml in the SCC counter are above limit of 10,000 cells/ml and below limit of 2,000,000 cells/mL. Milk's electrical conductivity was obtained from the milking system sensor (ENGS, EcoHerd, Version 1.01).

California mastitis test (CMT) analysis

CMT scores of all samples were determined by using a same solution, equipment and expert. Milk samples were homogeneously taken from each cow at the milking by using milk sampler. Then, milk samples were placed in a plastic test paddle, divided into 4 separate wells, in order to determine mastitis status. CMT solution was added on the milk samples taken and after mixing same direction in an oval shape for about 20 seconds, it was diagnosed by the expert (Shitandi and Kihumbu 2004).

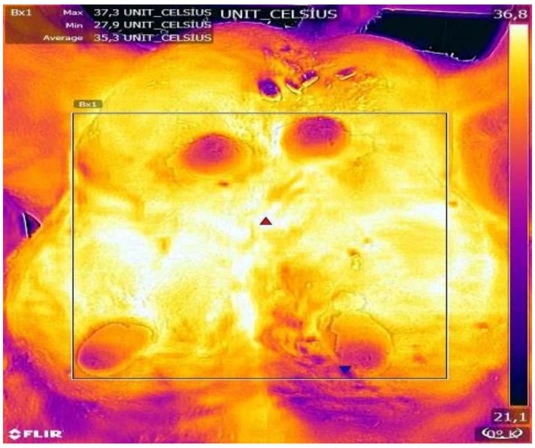


Figure 1
Thermal and normal udder images

Infrared Thermography and digital images processing

Thermal images were taken under the udder using FLIR One Pro before milking in the enterprise with parallel milking parlour. FLIR One Pro operates at 0°C – 35°C (32°F – 95°F) and can detect temperatures from -20°C – 400°C (-4°F – 752°F). Udder skin surface temperatures were determined using the FLIR tools program after taking the infrared thermal images. Lab (CIE L*, a*, b*), HSB (Hue, Saturation, Brightness) and RGB (Red, Green, Blue) values were determined by processing digital images with the Image-j program (Rasband, 1997). It represents the color change of L* between 0 (black) and 100 (white), green (-a) to red (+a) and blue (-b) to yellow (+b) in the digital image processing (CIE 1978). H, S and B color spaces are defined as Hue (H), saturation (S) and brightness (B), respectively. The use of the HSB color model is closer to the human eye's potential to see than the RGB model. The HSB color model is generally used for the separation of colored objects. Hue (H) is the portion of color that varies between 0 and 1 (or 0 to 360°) that corresponds in the position of the colorcylinder. Saturation (S) represents the amount of gray from 0 (gray) to 100% (main color) in the color. The brightness (V) indicates the brightness or intensity of the color ranging from 0 (Black) to 100% (brightest) (Joblove and Greenberg 1978). A thermal image taken under the udder using FLIR One Pro before milking are given in Figure 1.

Statistical analysis

CMT and CSCC such as subclinical mastitis diagnosis tests were binary dependent variables such as healthy and unhealthy. Also, udder skin surface temperatures, electrical conductivity and image processing parameters (L, a, b, Hue, Saturation, Brightness, Red, Green and Blue) were independent variables. In order to create the decision tree structure, threshold value for healthy or unhealthy of animals assumed to be a 200,000 cells/mL for CSCC and negative for CMT. That is, others were coded as unhealthy.There are many algorithms in decision treesin literature.CART (Classification and Regression Tree) data mining algorithm (Breiman et al. 1984) was used in this study. CART is a tree-based algorithm that is not in a mathematical form. It creates a binary classification tree by dividing a subset into smaller subsets. CART algorithm for decision tree-based diagnosis of mastitis has been preferred due to binary node splitting rule and visual results much easier to interpret recently. In the 10-fold cross-validation, the whole data set (102 records) was randomly divided into 10 approx. equal parts of 10 records, from which nine were used to train a given type of a prediction model and one served as an independent test set. This procedure was repeated 10 times (Eyduran et al. 2017; Aytekin et al. 2018). The Gini index was used as the division criterion. Accuracy, sensitivity and specificity formulas were calculated according to Mikail and Keskin (2015) and Aytekin et al. (2018). Confusion table for the classifier algorithms was given in Table 1.

Table 1
Confusion table for the classifier algorithms

		Predicted as	
		Unhealthy	Healthy
Observed	Unhealthy	X	Y
	Healthy	W	Z

Accuracy = (X+Z)/(X+Y+W+Z)

Sensitivity = X / (X+Y)

Specificity = Z / (W+Z)

Error proportion = 1 – Accuracy

$$se_{AUC} = \sqrt{\frac{AUC(1-AUC) + (n_A-1)(q1-AUC^2) + (n_B-1)(q2-AUC^2)}{n_A n_B}}$$

$n_A = X + W$ and $n_B = Y + Z$

$q1 = \frac{AUC}{2-AUC}$ and $q2 = \frac{2AUC^2}{1+AUC}$

In the above equation represent, X, Z, Y and W represent the numbers of true positive, true negative, false positive and false negative, respectively and formula was used from developed by Hanley and McNei (1982) to determine AUC (AUCse). Pairs of algorithms in area under ROC curve were compared on the basis of z test. IBM SPSS 23 (IBM Corporation, Armonk, New York, USA) statistical package program was used for CART algorithm for decision tree-based diagnosis of mastitis.

MedCalc trial version 19.5.1 was used to calculate the area under the ROC curve and its comparison (AUC) and compare the algorithm pairs in the field.

3. Results and Discussion

An infrared camera detects the thermal radiation emitted by a surface and the intensity of the emitted radiation is converted to temperature. Also, IRT can be static or dynamic. Infrared radiation emitted by a surface depends on the experimental conditions such as moisture, airflow and surrounding temperature. Hence, it is an absolute necessity for thermography experiments, especially in medical applications where temperature changes are within a few degrees, to be performed in controlled environments (Lahiri et al. 2012). Since the lactating cows were milked in the same environmental conditions in the milking parlor, the factors affecting the thermal image such as moisture, airflow and surrounding temperature had the same effect on all animals in this study.

Classification table of the CART algorithmwas given in Table 2. Classification performances for each diagnosis test of the CART algorithm and comparision of algorithms in area under ROC curve were given in Table 3. ROC curves were used to determine the usefulness of tests used to diagnose diseases. ROC curves for each diagnosis test of CART algorithm were depicted in Figure 2.

The areas under ROC (AUC) were found to be statistically significant in the diagnosis of subclinical mastitis (P<0.01). The sensitivity, specificity and accuracy of the CART algorithm for CSCC diagnosis test were 0.9020, 0.8039 and 0.8530, respectively. CSCC test of CART algorithm correctly classified 90.20% of unhealthy cows, 80.39% of healthy cows and 85.30% of all cows (P<0.000). The sensitivity, specificity and accuracy of the CART algorithm for CMT diagnosis test were 0.8542, 0.8148 and 0.8330, respectively. CMT test of CART algorithm correctly classified 85.42% of unhealthy cows (with mastitis), 81.48% of healthy cows and 83.30% of all cows (P<0.000). According to CART algorithm, there was no significant difference between SCC and CMT tests in the area under the ROC curve (P>0.05).

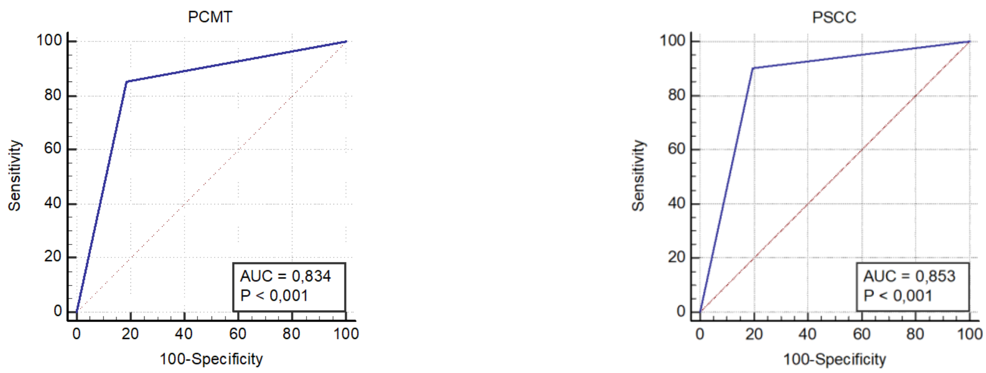
Table 2
Classification table of the CART algorithm

Dependent Variable		Predicted		
	Observed	Unhealthy	Healthy	Correct (%)
CSCC	Unhealthy	41	10	80.4
	Healthy	5	46	90.2
	Overall (%)	45.1	54.9	85.3
CMT	Unhealthy	44	10	81.5
	Healthy	7	41	85.4
	Overall (%)	50.0	50.0	83.3

Table 3
Classification performances for each diagnosis test of CART algorithm

Methods	Sensitivity	Specificity	AUC	Accuracy	P	Pairwise comparison of AUC P-value
CSCC	0.9020	0.8039	0.8530 ± 0.0351^{A}	0.8530	0.000	0.8279
CMT	0.8542	0.8148	0.8340 ± 0.0371^{A}	0.8330	0.000	

[A,] The difference between the algorithms with letter in CMT or CSCC column is not significant (comparison of the subclinical mastitis diagnostic tests)



CMT CSCC

Figure 2
ROC curve for each diagnosis test of CART algorithm

Classification tree diagram constructed by CART for CSCC test was given Figure 3. According to Figure 3, half of the 102 head Holstein-Friesian dairy cattle were classified as healthy and the other half as unhealthy in node 0. Node 0 was split into two smaller subgroups (Nodes 1 and 2) by electrical conductivity. In the first depth of the classification tree structure, cows whose electrical conductivity had 8.60 or lower in their milks were healthy at a percentage of 64.1 (Node1), but cows whose electrical conductivity had greater than 8.60 in their milks were characterized as unhealthy at the percentage of 95.8 (Node 2). Since the homogeneity is achieved at node 2 (split complete), the terminal node had been reached.

Cows in node 1 were classified into two smaller subgroups (Nodes 3 and 4) according to thermal temperature predictor. Cows whose electrical conductivity had greater than 8.60 in their milks and whose skin surface temperature had greater than 38.65 in their udders were unhealthy at the percentage of 56.8 (Node 4).

As for node 4, cows were classified into two smaller subgroups (Nodes 7 and 8) according to saturation predictor. While 69.2% of cows were healthy (Node 7) based on electrical conductivity (≤ 8.60), thermal temperature (> 38.65) and saturation (≤ 181856.5) predictors, 81.2% of cows were unhealthy (Node 8) based on electrical conductivity (≤ 8.60), thermal temperature (> 38.65) and saturation (> 181856.5) predictors.

Considering node 3, cows were classified into two smaller subgroups (Nodes 5 and 6) according to thermal temperature predictor. Indeed, 65.5% of the cows (Node 5) were found to be healthy if the electrical conductivity value had ≤ 8.60 (Node 1) and the thermal temperature value had > 38.65 (Node 3) in addition to the udder skin surface temperatures being ≤ 37.95. In addition to the previous nodes (1 and 3), similarly, 95% of cows (Node 6) with udder skin surface temperatures greater than 37.95 were found to be healthy. In other words, 95% of cows were understood to be healthy when udder skin surface temperature range was between > 37.95 and ≤38.65. This results also showed similarities with the udder skin surface temperature values 38.8 ±1 ºC in study made of Bitman et al. (1984) and 37.61 ºC in study made of Sathiyabarathi et al. (2018).

Node 5 was divided into two subgroups as Node 9 and 10 according to the Hue value. In addition to node 5, while 100% of cows having hue ≤ 64783.0 were found healthy (Node 9), 47.6% of cows having hue > 64783.0 were classified as unhealthy (Node 10).

Node 10 via CART algorithm was divided into two subgroups as node 11 and node 12 according to the L value. In addition to predictors down to node 10, while 100% of cows with L value ≤ 59788.0 were healthy (Node 11), 62.5% of cows with L> 59788.0 were classified as mastitis (Node 12). Classification tree diagram constructed by CART for CMT test was presented Figure 4. According to Figure 4, 102 head Holstein-Friesian dairy cattle as healthy and unhealthy were classified 52.9% and 47.1%, respectively in node 0.

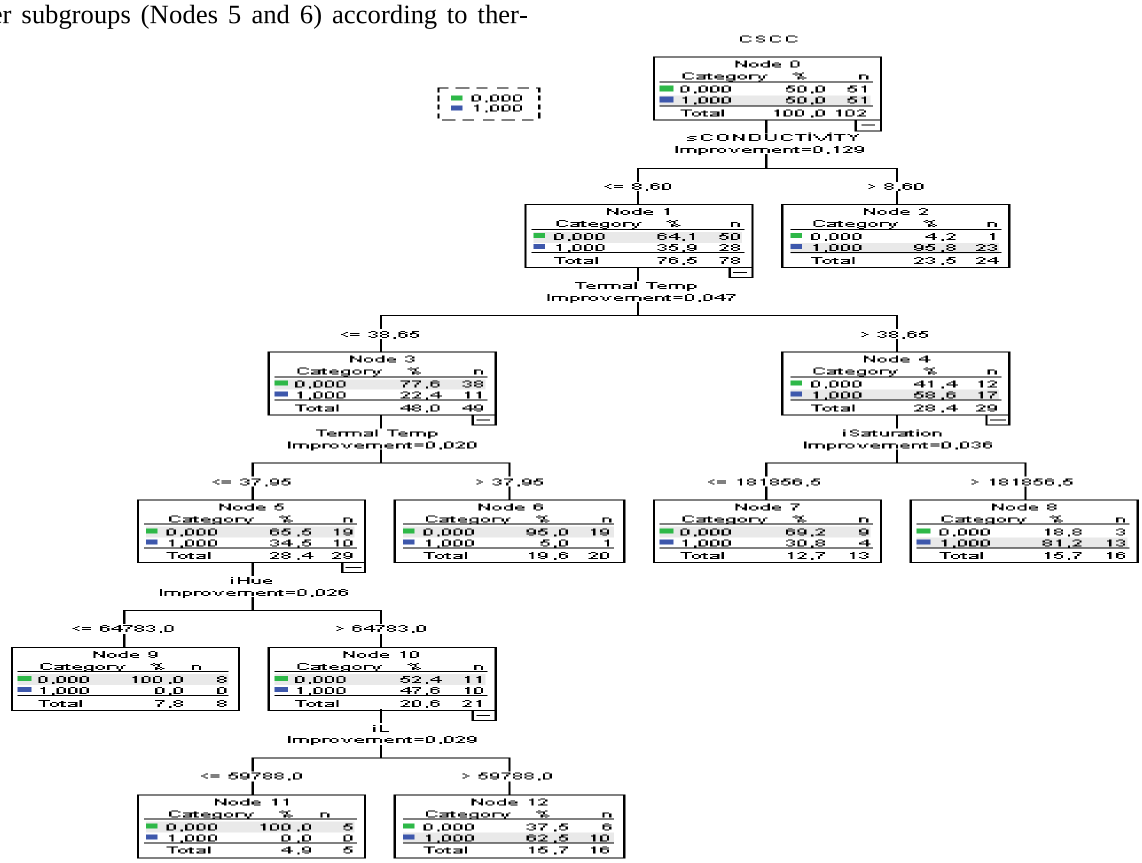


Figure 3
Classification tree diagram constructed by CART for CSCC test

Again as in CSCC, cows in node 0 were classified into two smaller subgroups (Nodes 1 and 2) according to electrical conductivity predictor in classification tree diagram constructed by CART for CMT test. In the first depth of the classification tree structure, cows whose electrical conductivity had 8.80 or lower in their milks were healthy at a percentage of 63.9 (Node1), but cows whose electrical conductivity had greater than 8.80 in their milks were characterized as unhealthy at the percentage of 94.7 (Node 2). Since the homogeneity is achieved at node 2 (split complete), the terminal node had been reached.

Cows in node 1 were classified into two smaller subgroups (Nodes 3 and 4) according to red predictor, one of the parameters obtained by processing thermal image. 53.8% of the cows (Node 3) were found to be healthy if the electrical conductivity value had ≤ 8.80 (Node 1) and the redness value of thermal temperature value had ≤ 226603.5 (Node 3). As seen on Note 4, 80.6% of cows with red value > 226603.3 were found to be unhealthy.

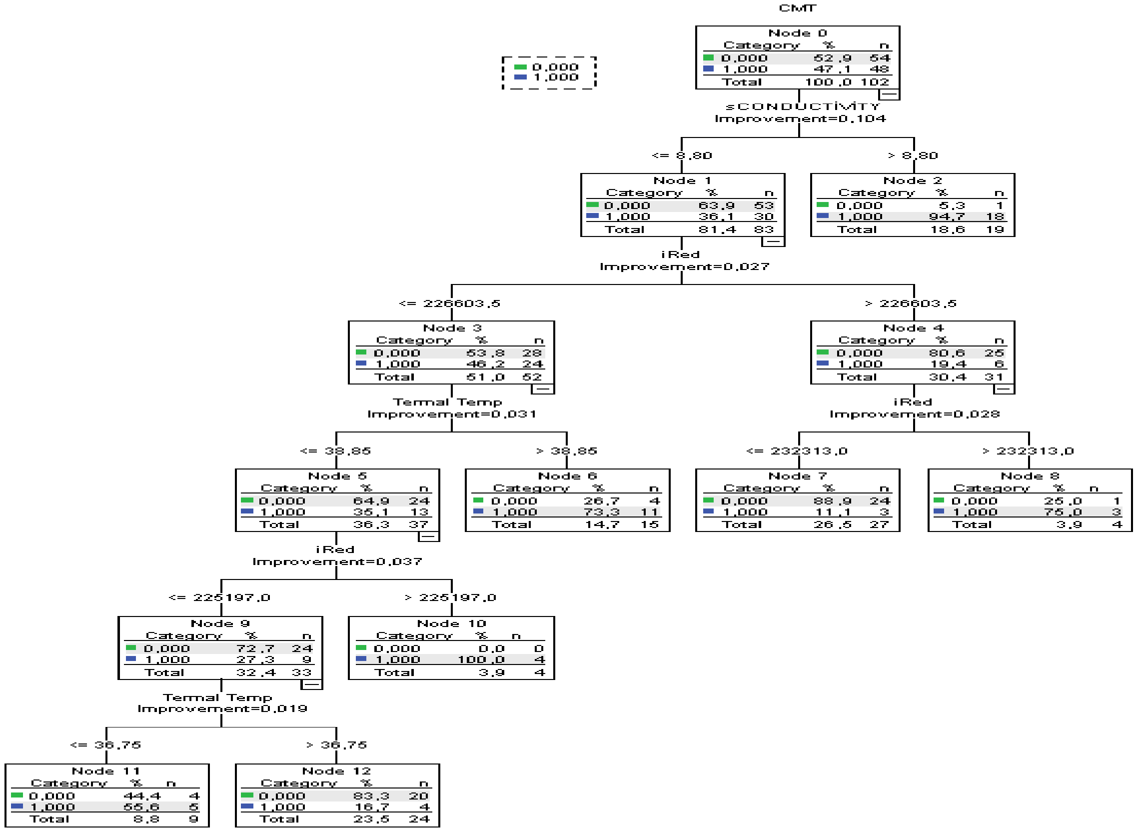


Figure 4

Classification tree diagram constructed by CART for CMT test

In node 4, while 88.9% of cows with electrical conductivity both with a value of ≤ 8.80 and with a range of 226603.5 <red ≤ 232310.0 in the node 7 were found to be healthy, 75% of cows with values of electrical conductivity (≤ 8.80) and red (> 226603.3 and > 232313.0) in the node 8 were classified as unhealthy.As for node 3, two subgroups as node 9 and 10 according to the udder skin surface temperature were classified. In node 5, 64.9% of cows with electrical conductivity with a value of ≤ 8.80, red with a value of ≤ 226603.5 and thermal temperature with a value of ≤ 38.85 were found to be healthy. Unlike node 5, 73.3% of cows with values thermal temperature with a value of > 38.85 were classified as unhealthy in node 6.

Cows in node 5 were classified into two smaller subgroups (Nodes 9 and 10) according to red predictor. 72.7% of the cows (Node 9) having electrical conductivity ≤ 8.80, red ≤ 226603.5, thermal temperature ≤ 38.85 and red ≤ 225197.0 were found to be healthy, As seen on Note 10, 80.6% of cows having red > 225197 was found to be unhealthy.

As for node 9, node 10 and 11 subgroups according to the udder skin surface temperature were classified. In addition to the classified predictors down to these subgroups, 55.6% of cows having udder skin surface temperature ≤ 36.75 and 83.3% of cows having udder skin surface temperature > 36.75 were found to be unhealthy and healthy, respectively.

There is a great deal of literature on both individual and combined use of diagnostic tests such as somatic cell count, California mastitis test and electrical conductivity value in the diagnosis of subclinical mastitis in dairy cattle until today (Baştan et al. 1997; Aytekin and Boztepe 2013; Aytekin and Boztepe, 2014; Aytekin et al. 2018; Aytekin et al. 2021). It has been proven in recent studies that the thermal camera is a useful tool in both diagnostic and physiological evaluations (Lahiri et al. 2012). The increasing performance of thermal cameras over time and their usability in different areas makes their use in livestocks very popular. IFT has been used in many areas in livestock until today, and some studies such as Bitman et al. (1984), Berry et al. (2003), Hovinen et al. (2008), Porcıonata et al. (2009), Polat et al. (2010), Metzner et al. (2014), Sathiyabarayhi et al. (2016), Pampariene et al. (2016), Golzarian et al (2017), Byrne et al. (2018), Juozaitienë et al. (2018) have been conducted for the diagnosis of mastitis in dairy cattle.

Bitman et al. (1984) reported that body and udder temperature in dairy cattle was 38.8 ± 1 ° C. In a study investigating the use of thermal camera for early detection of mastitis and its relation with other mastitis tests, udder surface temperatures of healthy, subclinical and clinical mastitis groups were 37.22, 38.08 and 38.25, respectively (Sathiyabarayhi et al. 2016). Researchers stated that thermal camera is a rapid and non-invasive technique for early detection of mastitis in dairy cattle. According to CMT by using CART analysis in this study, 64.9% of cows with udder surface temperature lower than 38.85 were healthy, and 73.3% of cows higher than 38.85 were determined as unhealthy. According to SCC, 77.6% of cows with udder surface temperature lower than 38.65 were healthy, and 58.6% of cows with higher than 38.65 were determined as unhealthy. The accuracy of these two systems is as high as 83.3% and 85.3%, respectively. Results obtained in the current study Bitman et al (1984) and Sathiyabarayhi et al. (2016) is compatible with the results reported.

Polat et al. (2010) compared the ability of thermal camera to detect mastitis with somatic cell count and california mastitis test results. The study showed that the sensitivity and specificity of the thermal camera (95.6% and 93.6%, respectively) did not differ from those of CMT (88.9% and 98.9%), there was a positive correlation between udder surface temperature and SCC (r = 0.73) and CMT (r = 0.86). The surface temperatures of udder lobes with negative +1, +2 and +3 CMT scores were determined as 33.23, 34.64, 35.75 and 36.27, respectively. The researchers reported that the thermal camera was successful in diagnosing subclinical mastitis. In the current research, the reason of udder surface temperature higher than study conducted by Polat et al. (2010) can be due to limiting factors use of thermal camera.

On the contrary, in the study was carried for detect subclinical mastitis at early stage, Porcıonata et al. (2009) stated that the diversity was important between different udder regions, also somatic cell count did not affect udder surface temperature (P>0.05). For this reason, the researchers stated that the thermal camera cannot be used in the diagnosis of subclinical mastitis. Golzarian et al. (2017) investigated the use of thermal camera in determining mastitis. Thermal image results were compared with SCC and CMT test results. They reported that the accuracy of this system is as low as 57.3%. Consequently, Porcıonata et al. (2009) and Golzarian et al. (2017) literature results and current study results do not compatible. This can be due to the lack of attention to factors that limit the use of the thermal imager. Environmental factors such as humidity, temperature, ventilation, wind, and sunlight significantly affect the imaging results. In addition to environmental factors, it is possible to minimize the errors in imaging when important issues such as the distance between the animal and the thermal camera, the angle of the thermal camera, the cleaning of the udder to be image and the physical activity of the animals before imaging (Cilulko et al. 2013; Coşkun and Aytekin, 2020).

4. Conclusion

The most important step in the sustainability of quality milk production and animal welfare in herd management is to know the factors that cause mastitis and to take the necessary precautions. Otherwise, severe economic losses from reduced milk production, treatment cost, increased labor, milk withheld following treatment and culling may happen in herd. In the present study, the results showed that there was a statistically significant relationship between udder skin surface temperature obtained via IRT technology and diagnostic tests such as SCC and CMT in the early detection of mastitis by CART algorithm (P<0.00). Accuracies of the CART algorithm for CSCC and CMT diagnostic test had high rate such a 85.30% and 83.30%, respectively.

In addition to being a fast, effective and non-invasive tool, IRT technology is sensitive enough to detect minor temperature changes on the breast surface caused by subclinical mastitis. Consequently, according to the classification tree diagram constructed by CART for CSCC and CMT diagnostic tests, the current study results showed that the use of thermal cameras in the early diagnosis of subclinical mastitis is a successful detection method. In addition, it can be stated that their reliability will increase even more when used in combination with other mastitis diagnostic methods by paying attention to the factors limiting the use of thermal cameras. Also, since IRT technology is likely to be used more in the livestock sector in the near future with the technological developments over time, more comprehensive studies should be needed.

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Utilizing Spent Plantain Pseudostems to Grow Vegetables for Additional Income to Farm Households in Nigeria

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ABSTRACT

The study examined value addition using plantain trunks to grow vegetables as an additional source of income to farm households. Using of a questionnaire to elicit responses from 120 plantain farmers in Edo State, we used descriptive and inferential statistics to examine the socioeconomic characteristics, return to leafy vegetable production, perceived environmental impacts and the challenges to adopting the innovation. Results from the study show that 62% of respondents were females. Lettuce and Spinach were the prevalent leafy vegetables grown. The return to leafy vegetable production was NGN, 258,378.42K/Ha/season fewer production costs. This return was 39% of the average returns to plantain production/Ha/Year. Decaying pseudostems adding to the manure to the soil through humus formation and reduced pollution from agrochemicals and fertilizers were some of the perceived environmental impacts of the innovation. Low market prices of vegetables, shortness of the shelf life of vegetables, costs of seeds were the major challenges encountered by farmers who adopted the innovation. The study concludes that the innovation was viable with the possibility of expansion. The study recommends further drive of the innovation to other plantain producing regions of Nigeria, and plantain farmers are also encouraged to explore other uses of their farm “waste”, environmental specialist and other promoters of eco-friendly production and investors should partner with these plantain producers to add value to products and ‘wastes’. The right and supporting policies to sustain the adoption of the innovation should also be put in place by the authorities concerned.

1. Introduction

Plantain belongs to the family of plants called “Musaceae”, and the principal species are *Musa paradisca* (French plantain), *Musa acuminata* (genome AA- Gross Michel and Cavendish) and *Musa. corniculata* (Horn plantain) whose production requires an optimum temperature of 30^{0}C, mean monthly rainfall of 100mm, soil pH of 4.5-7.5 and a partly drained sandy-loam soil (Ekunwe and Ajayi 2010; Ajiboye and Olaniyan 2016). Plantain is mainly grown in the tropical and subtropical countries and are widely used for its nutritional values all over the world (Imam and Akter 2011) and is one of the most important horticultural crops contributing to food security and alleviating hunger globally and serving as an important staple food for both rural and urban populace (USD, 2012). It meets their day-to-day food requirement in the form of chips, flour, flakes, cakes, fried plantain, roasted plantain, and so many other forms of culinary provisions, thereby contributing to the fight against food insecurity/poverty (Ojeniran et al. 2018). Nigeria is one of the largest producers of plantain globally and is ranked 7th in Africa and 15th in the world, producing 3,093,372 metric tons (FAOSTAT 2018). Ekunwe and Ajayi (2010); Akinyemi et al. (2017), and Elum and Tigiri (2018) listed Edo State as one of the States within the Southern Belt of Nigeria that grows plantain.

Whatever the variety of the fruit, all the parts of a Plantain plant have some use. However, the edible or direct human uses are considered while little or no attention is paid to the indirect uses. Imam and Akter (2011) and Okoli (2020a;b;c) and Voilette (2019) all posited that all the parts of the Plantain plant: fruit, peel, leaf, stem, stalk, and inflorescence (flower), can be utilized in agriculture and cottage industries. They are used in numerous food and non-food-related applications such as thickeners, colorants and flavorings, macro and micro-nutrient sources, livestock feed, fibres, bioactive compound sources, and organic fertilizers. Additionally, all parts of the Plantain plant

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have some medical values, for example, the flower can be cooked and consumed by diabetic, respiratory, dysentery, and ulcer patients. The stem sap can be administered orally or applied externally against stings and bites. The roots, ashed leaves, peels, and seeds are equally used for therapeutic purposes in some countries. The Plantain stem can be processed into pulp and paper raw material, fiber for textiles, and fillers, or structural reinforcement in composites materials.

Okoli (2020a) asserts that in many Plantain producing countries, particularly in Africa, Plantains are farmed for the fruits only, while the other parts are discarded as waste. Farm wastes are the by-products of farm activities and are so referred because they are not the primary products and could take the form of crop residues (residual stems, stalks, straw, leaves, roots, husks, shells) and animal waste (dungs) which are usually available, renewable and virtually free. They can be converted into a resource and raw materials that can be used for animal feed and composting, among others (Sabiiti 2011). It has been estimated that one hectare of the Plantain farm could produce approximately 220 tons of biomass wastes made of leaves, midrib, dried leaf sheath, pseudostem, and inflorescent flower. In Africa, these wastes are usually left on the farm to decay or are disposed of simply by burning. In large plantations, the disposal of large quantities of Plantain wastes can be costly, and constitute a major operation in order to avoid environmental damage and litigations (Okoli 2020b). Similarly, Obi et al. (2016) define farm wastes as the residues from the growing and processing raw farm products such as fruits, vegetables, meat, poultry, dairy products, and crops. They are the non-product outputs of the production and processing of agricultural products that may contain material that can benefit man but whose economic values are less than collection costs, transportation, and processing for beneficial use. This spells the necessity of utilizing farm waste as a resource to further production instead of discarding or leaving them to rot or even outright burning them in the field as obtained in developing countries. This is achievable through the process of innovation that Toborn (2011) defined as an idea, practice or object perceived as new by an individual or other unit of adoption.

On the attempts to use plantain waste, Belewu and Belewu (2005) explored the potential of Plantain leaves as a good substrate for the cultivation of *V. volvacea* and the spent substrate as a viable ingredient in ruminant feed, Phirke et al. (2001) stated that the Pseudo stem of plantain can be used for bio-fertilizer production and was supported by Kamira et al. (2015) as a source of compost manure and Vermicomposting. Okoli (2020b) also asserts that every part of the Plantain pseudostem can be converted into useful products using some simple techniques and technologies in turning such Plantain wastes into value-added by Plantain producers in Africa to generate extra income by creating lots of employment opportunities, especially for rural woman and unemployed youths, thereby improving their socioeconomic wellbeing.

While Lekshmi (2018) asserts that plantain trunk waste is used in Indonesia as planting material for growing short-root plants such as vegetables, he describes the innovation as having a positive effect on the country's agricultural scenario reduced tonnes of Plantain plant wastage that occurs regularly. The use of plantain stems from growing vegetables, as outline by Lekshmi (2018) entails digging appropriate holes (according to your crop or garden plant's features) in the stem with a knife, fill these with good loamy soil and plant the seeds into the pits at a spacing of 30 – 40cm between seedlings to avoid clustering, ensure proper aeration and balanced growth of plants. He further itemized the advantages of this innovation to include zero irrigation as the plantain stem has fantastic water retention abilities, so the plants absorb water from the stem and nutrients from the soil filled in the pits. There is a low chance of weed infestation, and the innovation encourages the availability of vegetables around the year irrespective of the season. Plantain stem cultivation can become the next revolutionary hack in the field of agriculture with the hope of bringing respite and good returns to the farmers. Ahmar (2021) describes the use of plantain stems to grow vegetables as an Organic farming innovation known for helping in minimizing space and resources principally because Plantain stems are easily available to farmers and serve as excellent devices for organic farming, particularly when their space is scarce. Therefore, he called for its drive especially in rural agriculture development that can help attain both the objectives of organic food and eliminate irrigation costs and further stated that rotten Plantain stems after use adds manures to the soil. It is, however, important to chop these into small pieces before they are used as a fertilizer. This helps to ensure that they do not become a hiding place for insects. The wonderful concept can go a long way in ensuring rural independence and cut away farmers' overreliance on rains or irrigation for moisture.

Adeoye et al. (2013) reviewed the significant contributions of plantain to the economic development and food security of both rural and urban households in Nigeria and outlined the need to understand the network, linkages, flow, volume and value added among the Plantain Value Chain actors. Despite several studies on the usefulness of plantains such as that Mohapatra et al. (2010), Ojeniran et al. (2018) and Okoli (2020a;b;c), there have been the concern of underutilization of some products of plantain and an assertion that some other potentials of plantain have not been discovered (Lekshmi 2018). In tandem with the study of Imam and Akter (2011) and Lekshmi (2018) that potentials of plantain based on the uses remain unexplored, limited and in-exhaustive, this study therefore explored the use of plantain trunks considered as a farm waste to grow vegetables in Nigeria as a source for additional farm income.

Specifically, we examine the socioeconomic characteristics of farmers who adopted the innovation, identified the types of vegetables grown using this innovation, return to leafy vegetable production, perceived environmental benefits and the challenges to adopting the innovation.

2. Materials and Methods

Study Area

The study was conducted in Ozalla Farm Reserve area of Owan West Local Government Area (LGA) of Edo State, Nigeria. The State is an agrarian State with farming as the dominant economic activity of the State while the area is located within Longitudes 6°45′ and 6°45.3′ and Latitudes 5°45′ and 5°47.5′ E. The area has a tropical climate characterized by two distinct seasons wet and dry seasons. The Wet season occurs between April and October with a break in August and average rainfall ranging from 1800mm –2500mm while the dry season lasts from November to April. The harmattan season is experienced between December and January. The various periods highlighted may vary slightly from recent climate change (Talabi et al. 2016). The target population for the study was an adopter of the innovation among plantain farmers in the Farm reserve area.

Experimental Design and method of data analysis

A two-stage purposive sampling procedure was employed for the study. The first stage involved the purposive sampling of Owan West LGA among the plantain producing LGA's. The second stage involved the selection of 120 plantain farmers who adopted the innovation.

Descriptive statistics of Frequencies tables and percentages was used to examine socioeconomic characteristics, perceived environmental impacts and the challenges to adopting the innovation while Net farm Income model was used to estimate the return to leafy vegetable production,

Model specification

Net Farm Income is the difference between gross income and total costs of production. Algebraically as adapted from Obalola, Agboola and Odum (2017), it is specified as:

GM = TR – TVC ----------------------------(1)

And

NFI = TR – TC -------------------------------(2)

Since,

TC = TVC + TFC ----------------------------(3)

Then

RTN = TR/TC --------------------------------(4)

Where,

GM = Gross Margin (NGN)

TR = Total Revenue (NGN)

TC = Total Cost (NGN)

TVC = Total Variable Costs of production (NGN);

TFC = Total Fixed Costs of production (NGN);

TC = Total Cost;

NFI = Net Farm Income (NGN)

RTN = Return to Naira invested

3. Results and Discussion

3.1. Socioeconomic report of respondents

The socioeconomic respondents who participated in using spent plantain pseudostems to grow vegetables for additional farm income is presented in Table 1.

Table 1
Socioeconomic report of respondents

Variable	Frequency (N=120)	Percentage (%)
Gender		
Male	46	38
Female	74	62
Age (years)		
≤ 20	16	13.3
21 – 30	30	25
31 – 40	30	25
41 – 50	24	20
≥ 50	20	16.7
Mean age	30.5years	
Marital Status		
Single	20	16.7
Married	50	50.0
Divorced	10	8.3
Widowed	30	25.0
Household Size (No. of persons)		
≤5	20	16.7
6 – 10	75	62.5
≥10	25	20.8
Mean Household Size	8 persons	
Level of Education		
No formal Education	25	20.8
Primary/Basic	35	29.2
Secondary	40	33.3
Tertiary	20	16.7
Farm Size (Ha)		
≤5	25	20.8
6 – 10	60	50.0
≥10	35	29.2
Mean Farm Size	8 Hectares	
Farming Experience (Years)		
≤5	10	8.3
6 – 10	50	41.7
11 – 15	40	33.3
≥15	20	16.7
Mean Farming Experience	10years	
Income level(NGN/Ha/Cycle)		
≤ 300, 000	45	
300, 000 – 600, 000	60	
≥ 600, 000	15	
Mean income	NGN/Ha/Cycle 662, 508.77	

Source: Field Survey, 2020

The results in Table 1 show the socioeconomic characteristics of the respondents who adopted the technology. Using Plantain pseudostems to grow vegetable is a female dominated ventures as 62% of respondents were females. The modal age of respondents was between 21 – 30 and 21 – 40 with a mean age of 30.5years. About 50% of the respondents were married while 16/7% were not married. The modal household size of respondents was between 6 – 10persons per household while the mean household size of respondents was 8 persons. On the respondent level of education, 79.2% had a form of education or the other while 20.2% had no formal education. The respondent level of education may largely influence their willingness or not to adopt the technology. With a mean farm size of 8 Ha and 10 years farming experience, respondents made an average of NGN662, 508.77K/Ha/Cycle.

3.2. Identified vegetables grown on using the innovation

Results in Figure 1 show that 45.6% of respondents grew lettuce; 41.7% grew onions while 12.5% grew Spinach using the spent plantain pseudostems.

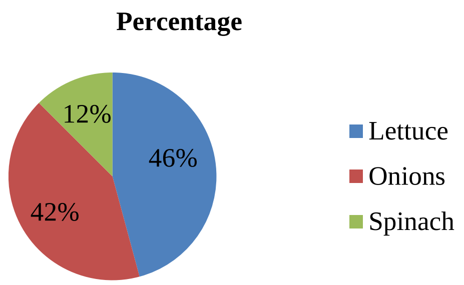

Figure 1
Vegetables grown using spent plantain pseudostem (Source: Field Survey 2020)

3.3. Return to Vegetable production using plantain trunks for growing vegetables

The costs and return to vegetable production using this innovation is presented in Table 2.

Using spent plantain pseudostem to grow vegetables, farmers incurred NGN 88, 202.5 as total variable cost and NGN 58,100 as total fixed cost in their production. Farmer earned a total of NGN 398, 380.92k as total revenue. However, they had a return (NFI) of NGN 258, 378.42/Ha/cycle less the total cost incurred in production. The use of spent plantain to grow vegetables had 2.8 as return to Naira invested which imply that for every Naira invested in the innovation a corresponding NGN 2.8 was returned as profit of investment which show that investing in the use of spent plantain psuedostems to grow vegetables is viable and should be encouraged to reduce farm waste and create some additional farm income for plantain farming households in the study area. Additionally, the costs for farm yard manure (28.3%) and acquiring Knapsack spray tanks (69.4%) were the highest incurred for variable cost and fixed cost, respectively.

Table 2
Return to vegetable production using spent plantain pseudostem for additional farm income

Variable Cost	Cost/Unit (NGN)	Qty/Ha	Amount (NGN)	%
Seeds (Kg)	5,000	2	10,000	11.3
Insecticides (Litres)	1,470	2	2,940	3.3
Farm yard manure (Kg)	500	50	25,000	28.3
Transportation (NGN/day)	1,630	12	19,560	22.2
Water for spraying insecticides (Litres)	33.5	215	7,202.5	8.2
Pseudostem collection and preparation (Manday)	1,640	3	4,920	5.6
Insecticide Application (Manday)	1,580	3	4,740	5.4
Farm Maintenance (Manday)	2,000	2	4,000	4.5
Harvesting/Sorting (Manday)	1,550	3	4,650	5.3
Basketing and packaging (Manday)	1,730	3	5,190	5.6
Total Variable Cost (TVC)			88, 202.5	100
Fixed Cost				
Cutlasses (NGN/Unit)	2,000	4	8,000	15.4
Knives (NGN/Unit)	450	6	2,700	5.2
Basket (NGN/Unit)	1,700	3	5,100	10
Knapsack Sprayers (NGN/Unit)	12,000	3	36,000	69.4
Total Fixed Cost (TFC)			51, 800	100
Total Cost (TC)			140,002.5	
Revenue			398,380.92	
Gross Margin			310,178.42	
Net Farm Income (NFI)			258,378.42	
Return to Naira invested			2.8	

Source: Field Survey, 2020

3.4. Perceived environmental benefits of the innovation

On the perceived benefit of this innovation to the environment as shown in Figure 2, 50% of respondents believe that when spent plantain pseudostems are used in growing crops, they decay, form and add humus to the soil which is an essential constituent of soil fertility and hence reduce the additional requirement for fertilizers. About 41.7% of farmers who adopted this innovation believe there will be reduced pollution due to agrochemicals and fertilizers because the innovation is soil fertility replenishing. This partly agrees with Lekshmi (2018) who stated that the innovation makes the chances of weed infestation remain relatively lower and consequently will cut off weeding cost. Also, 8.3% of respondents opined that the innovation would prevent moisture loss by plants if grown on the soil because plantain pseuedostems retain water over a long time. The innovation is self moisture servicing and sustaining. This is in tandem with Ahmar (2021) who stated that the innovation retains water to the tune of serving the purpose of irrigation for farmers and encourages farmers to use the plantain pseudostems for planting short root crops.

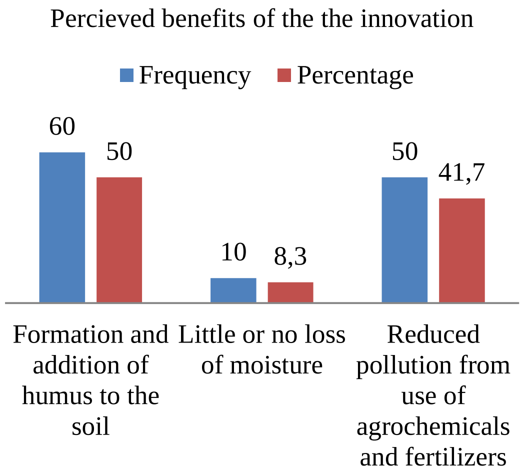

Figure 2
Benefits of using spent plantain pseudostems to grow vegetables to the environment (Source: Field Survey, 2020)

3.5. Constraints to adopting the innovation

Results from Table 3 show that Low market prices of vegetables ranked the 1st among constraints encountered by farmers who adopt this innovation. They take time to tend for their plants during the dry season only to take their produce to the markets and it is priced very low. Lack of access to improved/hybrid seed ranked the 2nd. In contrast, high cost of seeds and invasion of farms by herds ranked the 3rd respectively and shortness of the shelf life of vegetables ranked the 5th principally because farmers wish the fresh vegetable stays longer and service the consumers in the dry season and absence of extension education and farm advisory services ranked the least (6th position) among the challenges encountered by farmers in the adopting of this innovation.

Table 3
Constraints to adopting the innovation

Variable	Frequency	Percentage	Rank
Low market prices of vegetables	30	25.0	1st
High cost of seeds	20	16.7	3rd
Lack of access to improved seed	25	20.8	2nd
No extension education	10	8.3	6th
Short shelf life of vegetables	15	12.5	5th
Herds invasion of farm	20	16.7	3rd

(Source: Field Survey, 2020)

4. Conclusion and Recommendation

We conclude this study by stating that, growing vegetables with spent plantain psuedostem is a female dominated activity. Lettuce and Spinach were the prevalent leafy vegetables grown using the innovation. Leafy vegetable production is profitable and cost effective in the study area. Decaying pseudostems adding to the manure to the soil through humus formation and reduced pollution from agrochemicals and fertilizers were some of the perceived environmental impacts of the innovation. Low market prices of vegetables, shortness of the shelf life of vegetables, costs of seeds were the major challenges encountered by farmers who adopted the innovation. We are of the option that the innovation was viable with possibility of expansion. The study recommends further drive of the innovation to other plantain producing regions of Nigeria, plantain farmers are also encouraged to explore other uses of their farm 'waste', environmental specialist and other promoters of eco-friendly production and investors should partner with these plantain producers to add value to products and 'wastes'. The right and supporting policies to sustain the adoption of the innovation should also be put in place by the authorities concerned.

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Physical Characteristics and Natural Flow Rates of Dry Bean Cultivars of a Local Population Grown in Konya Province of Turkey

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ABSTRACT

In the present study, physical characteristics of some dry bean cultivars (Sarikiz, Basara and Horoz) of a local population grown in Konya province of Turkey were determined and an experimental test set up was used to investigate flow rates on different surfaces (galvanized sheet, plain sheet and painted sheet iron) and different conveyor channel angles (24^0, 28^0, 32^0, 36^0). In Sarikiz, Basara and Horoz dry bean cultivars respectively at 10.85, 9.63 and 9.12% moisture levels, average grain lengths were respectively measured as 11.51, 17.56 and 15.09 mm; average widths 7.21, 10.40 and 7.31 mm; average thicknesses as 5.11, 4.92 and 5.76 mm; average geometric mean diameters as 7.51, 9.64 and 8.59 mm; sphericity values as 0.65, 0.55 and 0.57; angle of repose values as 20.07^0, 21.99^0 and 18.53^0; thousand-kernel weights as 229.60, 514.93 and 426.67 g; bulk densities as 682.72, 696.65 and 779.17 kg m^{-3}. Static coefficient of friction values of the same cultivars (Sarikiz, Basara and Horoz) on galvanized, painted and plain sheet surface were respectively measured as 0.356, 0.441 and 0.427; 0.350, 0.428 and 0.396; 0.344, 0.401 and 0.383. In Horoz dry bean cultivar, the flow was seen on all surfaces and at all channel angles. However, there was no flow in Sarıkız and Basara cultivars on painted sheet surface at 24^o channel angle and no flow in Sarıkız cultivar on plain sheet surface at 24^o channel angle. Among the cultivars, the greatest average flow rate (1.61 kg s^{-1}) was achieved in Horoz dry bean cultivar and such a flow rate was mostly designated by grain physical characteristics and surface profile. Surface roughness influenced flow rates and the greatest flow rate on galvanized sheet surface with the lowest surface roughness was measured as 1.66 kg s^{-1}. The greatest flow rate was obtained from 36^0 conveyor channel angle (2.01 kg s^{-1}). Present findings revealed that physical characteristics of the cultivars, channel roughness and angle influenced flow rates.

1. Introduction

With the increasing world population, human nutrition has become an important issue. Decreasing agricultural lands per capita, changing consumer demands and the formation of a wide range of consumptions entail the development of several high-yield varieties. Pulses including beans, lentils, broad beans and cowpea play a great role in the solution of human nutrition-related problems.

Beans are consumed as fresh or dry bean. Beans are rich in protein and the amino acid composition of bean proteins is quite close to meat protein. Beans are also rich in carbohydrates, calcium, iron and especially phosphorus, thus have a superior position over the similar foodstuffs. On the other hand, sulphur-containing amino acid content of beans is greater than the edible pulses, thus the biological value of bean protein is high (Çavuşoğlu and Akçin 2007).

Dry bean (white bean) production areas, yield and production of Turkey and Konya province are provided in Table 1. According to 2020 data, in Konya province, dry bean farming was practiced over 185 900 da land areas and total production was 62 408 tons. Dry bean cultivated lands of Konya province constitute 18.5% of the country production area and 22.335 of country production. Yield levels are also 124% greater than the country average.

Local cultivars are highly adapted to growing the region, have a high-quality trait and mostly emerged through local selections. Today, mostly the local cultivars are grown and served to markets. These cultivars are also used in breeding studies conducted to develop new cultivars Since the local cultivars are grown with the use of conventional farming systems, the produc-

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tion of these cultivars does not comply with organic farming principles.

The physical and mechanical properties of grains play an important role in the selection of storage equipment and design of storage structures (Kashaninejad et al. 2006).

Table 1
Dry bean cultivation area, yield and productions of Turkey and Konya province (TÜİK, 2021)

	Cultivated land (da)		Yield (kg da^{-1})		Production (ton)	
Years	Konya	Turkey	Konya	Turkey	Konya	Turkey
2015	191 849	935 840	380	251	72 869	235 000
2016	202 234	898 197	367	265	69 877	235 000
2017	191 438	897 221	367	267	70 242	239 000
2018	148 111	848 045	361	259	53 439	220 000
2019	148 331	889 385	335	253	49 664	225 000
2020	185 900	1 029 857	336	271	62 408	279 518

Flow characteristics of granular products cannot be explained by fluid mechanics and hydrodynamic principles. Some agricultural products flow more easily as compared to the others. Non-uniform pressure distribution and frictional forces between the particles lead to problems such as product caking during storage, non-uniform arching and channeling etc.

The orifice shape and physical properties of the material affect the flow rate of the material. The shape of the grain and the grain shape distribution play an important role in flowability, while the unit weight affects the internal friction angle and compressibility of grain (Fitzpatrick et al. 2004).

Many studies have focused on the material flow rate, the relationship between flow rate and material properties and the regularity of the flow in various orifices. For instance, Mohsenin (1986) investigated the factors affecting grain flow such as bin geometry, orifice shape, height / diameter ratio of orifice factors and obtained several mathematical equations which define the grain flow.

Kara and Ozturk (1997) investigated the factors that affect the flow from the orifice in the different formats of grain products and developed mathematical equations to find the flow rate of the products.

Elaskar et al. (2001) recorded a video of the flow from rough and smooth channels of sorghum and obtained velocity profiles. Researchers reported 113 % increase in velocity when the sliding surface slope angles increase from 18^0 to 38^0; they found that the maximum velocity occurred at a slope angle of 37^0; and the flow rate increased 377% when the slope angle was increased from 30^0 to 37^0.

Akar (2003) reported that natural flow rates of Sultani and Amasya okra varieties changed depending on the moisture condition, the flow angle and type of channel. The study determined that flow rates of both varieties decreased as the moisture content increased and there was no natural flow for a slope angle of 30^0 with respect to the moisture content. Furthermore, the highest flow rate values for both varieties were obtained when using a galvanized steel channel.

In Turkey, there are several ongoing investigations on the flow profiles of granular products in silos (Ozturk et al. 2008a) and design loads for nuts and corn in storage buildings (Ozturk et al. 2008b;c).

In the transport of grain products by mechanical transmission systems, the loading and unloading system transmission channels and the slope angle of the base walls of the silo are extremely important for a continual natural flow. Therefore, in this study, the natural flow rates of some dry beans varieties were determined for different flow surfaces and angles. Some physical characteristics and natural flow rates of dry beans of a local population were determined for different flow surfaces and angles.

2. Materials and Methods

Sarıkız, Basara and Horoz dry bean varieties, all of which are cultivated in Konya province, were used as the material of the present experiments.

The thousand grain weight of beans were measured by using an electronic balance with an accuracy of ±0.001 g. Initially, 100 grains were taken randomly in three replicates for each variety to measure the thousand grain weight. Dimensional properties of grains were measured by using a micrometer with ±0.01 mm accuracy. Geometric mean diameter (D_g) and sphericity (Ø) values were calculated with the use of the following equations (Mohsenin 1986).

$$D_g = (LWT)^{0.333}$$

$$Ø = (LWT)^{0.333} / L$$

Where,

D_g : Geometric mean diameter (mm)

Ø : Sphericity (-)

L : Length of grain (mm)

W : Width of grain (mm)

T : Thickness of grain (mm)

To determine the angle of repose, the materials were slowly poured on a flat surface freely. Poured materials formed a cone on the surface. The angles of repose were determined by calculating the tangent value (internal friction coefficient) of the horizontal angle of this cone (angle of repose).

Each cultivar was poured into a one-liter glass vessel with the velocity of 12 s/L. After pouring, the vessel top was leveled off, then the weight of the material was determined. The resultant weight was divided by the volume of the vessel to get the bulk density of the material.

The coefficient of static friction was measured by using sheet iron, galvanized sheet iron and painted sheet surfaces. For this measurement, one end of the friction surface is attached to an endless screw. Dry bean samples were placed on the surface and it was gradually raised by the screw. Vertical and horizontal height values were read from the ruler when the grain started sliding over the surface, then using the tangent value of that angle, the coefficient of static friction was found. Baryeh (2001) and Gezer et al. (2003) have used similar methods.

The flow rate values were determined in the experimental test unit, which was constructed specifically for this purpose. The experimental test unit consists of a cylindrical feeding hopper, which has a funnel-shaped exit with a capacity of five liters; an unloading cover can be opened easily at the bottom of the hopper, and a channel conveyor. The channel conveyors which have three different surfaces and have a 0.5 m length, were used in the experiment. These channels consist of: formed steel, galvanized steel and painted steel sheet. A special structure was constructed to support the hopper and the channel. A schematic view of this experimental test unit is given in Figure 1.

During the trials, after a funnel-shaped hopper was filled with material, the unloading cover at the bottom of the storage was opened, and the digital chronometer was operated simultaneously. After all of the material entered into the channel conveyor, the chronometer was stopped and the elapsed time was determined. These values were divided by the mass of the material, and the natural flow rates were determined in three replicates

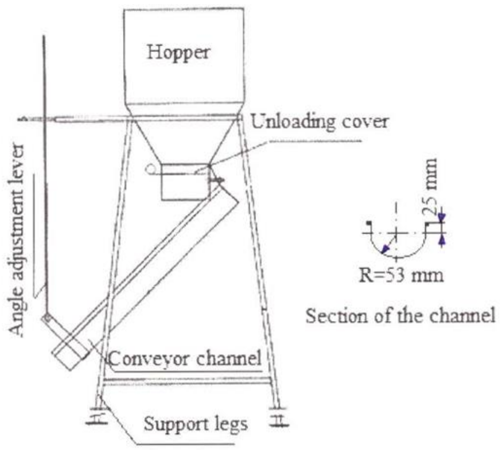

Figure 1
A schematic view of the natural flow test unit and section of the channel

There are three values to define surface roughness: Ra (the mathematical average roughness value), R_z (the measured roughness value) and Rmax (the biggest surface roughness). R_a, R_z and R_{max} values were measured by the profile-meter device (measurement range of 0-150 µm, Marsurf brand) in the three replicates.

Experimental data were subjected to ANOVA with the use of the General Linear Model of MİNİTAB 16 software. Significant means were compared with the use of Tukey's multiple range test.

3. Results and Discussion

Physical characteristics of present dry bean cultivars are provided in Table 2. The greatest grain length, width, geometric mean diameter and angle of repose values were obtained from Basara cultivar respectively with 17.57 mm, 10.40 mm, 9.64 mm and 21.99^0. In Basara cultivar, low values of thickness and sphericity (4.92 mm and 0.55) were observed. The greatest bulk density (779.17 kg m^{-3}) was obtained from Horoz cultivars and the lowest bulk density (682.72 kg m^{-3}) Sarıkız cultivar. The thousand-grain weight of Sarıkız, Basara and Horoz cultivars was respectively measured as 229.60, 514.93 and 426.67 g. The coefficient of static friction values for galvanized sheet, painted sheet and steel sheet surfaces varied from 0.344 to 0.441.

The lowest values were obtained from the galvanized sheet surface and the highest values from the painted sheet surface. Güngör and Güvenç (1996) conducted a study on registered dry bean cultivars of Turkey and reported that grains lengths varied between 8.6 mm (Karacaşehir) and 15.5 mm (Şahin-90), grain widths between 5.5 mm (Karacaşehir-90) and 7.7 mm (Şeker), grain thicknesses between 4.6 mm (Karacaşehir-90) and 6.7 mm (Şeker), and thousand grain weights between 209.1 g (Karaeaşehir-90) and 467,6 g (Yunus-90). Işık and Unal (2007) conducted a study on white speckled red kidney bean grains at 9.77% moisture level and reported geometric mean diameter as 9.38 mm and sphericity value as 0.734. Present findings on physical characteristics comply with literature findings.

The changes in R_a, R_z, and R_{max} values, which determine the surface roughness of the channel conveyors, are given in Table 3. The maximum values of roughness (R_{max}), the mathematical mean roughness values (R_a) and the measured roughness values (R_z) of the galvanized sheet surface, the steel sheet surface and the painted sheet surface were found to be 6.20, 8.12 and 19.18; 1.13, 1.20 and 2.06; 4.83, 6.42, and 11.56, respectively.

The natural flow rate values for different surfaces and channel conveyor angles are provided in Table 3. By increasing the channel conveyor angles, the natural flow rate values increased on all surfaces. For the channel angle of 24^o and painted sheet surface, it was observed that there was no flow in Sarıkız and Basara dry bean cultivars. Again, in the Sarıkız cultivar, there was no flow on the plain sheet surface at 24^o channel angle. Such a case was because of high static coefficient of friction (friction angle) of the grains on these surfaces.

Table 2
Some physical characteristics of dry bean grains

Characteristics	Sarıkız cultivar	Başara cultivar	Horoz cultivar
Moisture (%)	10.85	9.63	9.12
Lenght (mm)	11.51±0.12	17.56±0.17	15.09±0.13
Width (mm	7.21±0.07	10.40±0.08	7.31±0.06
Thickness (mm)	5.11±0.05	4.92±0.08	5.76±0.05
Geometric mean diameter (mm)	7.51±0.061	9.64±0.076	8.59±0.060
Sphericity (-)	0.65±0.003	0.55±0.004	0.57±0.002
Angle of repose (^{0})	20.07±0.56	21.99±0.71	18.53±0.98
Thousand-grain weight (g)	229.60±1.71	514.93±3.41	426.67±6.67
Bulk density ($kg.m^{-3}$)	682.72±4.13	696.65±4.92	779.17±3.65
Static coefficient of friction			
Galvanized sheet surface	0.356±0.011	0.350±0.017	0.344±0.010
Painted sheet surface	0.441±0.015	0.428±0.011	0.401±0.013
Steel sheet surface	0.427±0.013	0.396±0.010	0.383±0.014

Table 3
Surface roughness values

	R_{max}	R_a	R_z
Galvanized sheet surface	6.20±0.35	1.13±0.06	4.83 ±0.27
Plain sheet surface	8.12±0.74	1.20±0.06	6.42±0.30
Painted sheet surface	19.18±3.84	2.06±0.07	11.56±1.14

In Horoz cultivar, grain flow on painted sheet surface (with high roughness) at 24^0 channel angle was mostly resulted from low angle of repose of the material. The angle of repose of granular materials plays an important role in design of conveyors.

Variance analysis on natural flow rates of different dry bean cultivars at different channel angles on different conveyance surfaces revealed that there were significant relationships between all parameters and levels (Table 4). The highest flow rate value was obtained as 2.26 kg s^{-1} in the horoz bean variety, on the galvanized sheet surface and at the 36 degree conveyor channel angle.

Table 4
Natural flow rates over different surfaces and at different channel conveyor angles (kg s^{-1})

	Conveyor channel angle			
	24^o	28^o	32^o	36^o
Galvanized sheet surface				
Sarıkız cultivar	0.87±0.0$_{jk}$	1.50±0.02$_{f}$	1.87±0.03$_{cd}$	2.07±0.05$_{b}$
Başara cultivar	0.91±0.02$_{j}$	1.47±0.01$_{fg}$	1.77±0.05$_{cde}$	1.91±0.04$_{c}$
Horoz cultivar	1.26±0.02$_{hı}$	1.85±0.01$_{cd}$	2.17±0.01$_{ab}$	2.26±0.01$_{a}$
Painted sheet surface				
Sarıkız cultivar	-	1.15±0.01$_{ı}$	1.67±0.01$_{e}$	1.83±0.01$_{cd}$
Başara cultivar	-	1.35±0.01$_{gh}$	1.68±0.02e	1.84±0.01$_{cd}$
Horoz cultivar	1.22±0.01$_{hı}$	1.65±0.03$_{e}$	1.89±0.01$_{cd}$	2.06±0.02$_{b}$
Plain sheet surface				
Sarıkız cultivar	-	1.23±0.03$_{hı}$	1.82±0.02$_{cd}$	2.05±0.02$_{b}$
Başara cultivar	0.76±0.02$_{k}$	1.41±0.01$_{fg}$	1.75±0.02$_{de}$	1.89±0.01$_{cd}$
Horoz cultivar	1.26±0.02$_{hı}$	1.83±0.04$_{cd}$	2.11±0.04$_{ab}$	2.12±0.03$_{ab}$

In terms of average flow rates, the greatest value was measured as 1.61 kg s^{-1} in Horoz cultivar, 1.40 kg s^{-1} in Basara cultivar and 1.34 kg s^{-1} in Sarıkız cultivar and the differences in natural flow rates of the cultivars were found to be significant ($p<0.05$). High flow rate of Horoz cultivar was attributed to grain surface profile with low angle repose and static coefficient of friction.

Increasing flow rates were observed on galvanized sheet surface with increasing conveyor channel angles. On this surface, the flow rate increase ratio in Sarıkız, Basara and Horoz cultivars was respectively calculated as 240, 210 and 179%. Such increases on painted sheet surface were respectively calculated as 159, 136 and 169% and increases on plain sheet surface were respectively calculated as 167, 249 and 168%. In terms of average flow rate, the value was measured as 1.66 kg s^{-1} on the galvanized sheet surface, 1.36 kg s^{-1} on painted sheet surface and 1.52 kg s^{-1} on plain sheet surface and the differences between average flow rates of the surfaces were found to be significant ($p>0.05$). Such differences were mainly attributed to surface roughness values. The greatest average surface roughness value was observed on galvanized sheet surface (1.13 µm) and the lowest on painted sheet surface (2.06 µm) (Table 3).

In terms of flow rates, there were significant differences between conveyor channel angles. The average flow rate at 36^0 channel angle was measured as 2.01 kg

s^{-1} ($p>0.05$). High channel angles increased flow rates and decreased flow depths. Elaskar et al. (2003) indicated that flow rate and maximum stable flow depth of sorghum grains exhibited almost a linear relationship with channel angle.

4. Conclusion

There were significant differences in physical characteristics of dry bean cultivars of a local population grown in Konya province. There was no flow in Sarıkız and Basara cultivars on painted sheet surface at 24° channel angle and no flow in Sarıkız cultivar on plain sheet surface at 24° channel angle. Therefore, to achieve flow on these surfaces, a greater channel angle than the static coefficient of friction (friction angle) should be selected. Such an issue should be taken into consideration especially for surfaces with high surface roughness. Present observations revealed that periodical cleaning of the channel base will lead to greater flow rates. In the present study, experimental observations were presented without a theory. Further research is recommended for velocity profiles and flow characteristics of granular materials.

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The Effects of Fungicidal Seed Treatments on Seed Germination, Mean Germination Time and Seedling Growth in Safflower (*Carthamus tinctorius* L.)

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ABSTRACT

Seed-borne pathogens cause incorrect scores determining seed germination rate in safflower. A laboratory experiment was planned to search for an effective fungicide treatment for safflower seeds inhibiting the seed-borne infections during germination and early seedling growth. Two safflower cultivars (Olas and Linas) and five fungicides (Thiram, maneb, mancozeb, metalaxyl, and captan) were tested. Germination, mean germination time, and seedling growth parameters were investigated for determining the effectiveness of the fungicides. Results showed that germination percentage was not adversely affected by the fungicides and a higher germination percentage was obtained from the seeds treated with fungicides. Mean germination time shortened with fungicide treatments and more rapid germination was observed in thiram and metalaxyl. Fungicides increased root and shoot growth, especially in thriam and metalaxyl. The seedling weight of safflower cultivars was not changed by the application of fungicides. The infection rate of two safflower cultivars was different and untreated seeds of cv. Olas were infected. The seeds treated with fungicides successfully prevented the seed-borne infections, the minimum infection rate was obtained from the seeds treated with thiram, maneb and mancozeb. It was concluded that pretreatment of safflower seeds with thriam or mancozeb should be beneficial for avoiding seed-borne pathogens before germination test, and these applications may be tested under field conditions in terms of emergence and seed yield performance.

1. Introduction

Safflower (*Carthamus tinctorius* L.) is one of the most promising oilseed crops to meet the vegetable oil demand because it is adapted to drought and saline conditions under rainfed conditions in Turkey (Kaya et al. 2019). It belongs to the *Asteraceae* family and its seeds are called an achene. Achenes contain a single seed covered by pericarp, which makes achene suitable for placing the pathogens between seed and the pericarp. These pathogens like fungi, bacteria, and viruses adversely affect germinating seeds, seedling development, and healthy plant growth. Seed-borne pathogens prevent directly and indirectly the uniform seedling emergence and stand establishment of safflower due to reduction in germination and viability of seed (Pawar et al. 2013). For these reasons, they must be controlled by seed treatments.

Fungal pathogens are the most hazardous pathogen damaging germinating seeds and early seedling development of safflower. The most common fungi are Alternaria blight (*Alternaria carthami*), Fusarium wilt (*Fusarium oxysporum* Schlecht. f. sp. *carthami*), Verticillium wilt (*Verticillium albo-atrum*), Phytophthora root rot (*Phytophthora drechsleri*), rust (*Puccinia carthami*), brown leaf spot (*Ramularia carthami*), Cercospora leaf spot (*Cercospora carthami*), and Macrophomina root rot (*Macrophomina phaseolina*) (Chattopadhyay et al., 2015). However, several fungicides and their combinations have been extensively used for controlling these pathogens (Pawar et al. 2015). In previous studies, Sudisha et al. (2006) and Pawar et al. (2013) found a significant reduction in disease indices with pre-sowing fungicidal seed treatments. Similarly, Ellis et al. (2011) reported that seed treatments with captan and fludioxonil alleviated fungi damage by 46% and 48%, respectively over control in soybean. Addrah et al. (2020) observed that different rates of pathogen contamination on sunflower varieties and fungicide application decreased in contamination rate from 98% to less than 10%. According to Bardin et al. (2003)

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Pythium species, which damage seedling growth in peas, sugar beet, canola, and sunflower, decreased with Thiram application, as well as increased seedling emergence rates in the field. Inhibited seed-borne fungi in rice associated with seed treatments with mancozeb, metalaxyl, benomyl, carbendazim and thiram was reported by Ibiam et al. (2008). In our study, it was aimed to determine if there are the beneficial effects of some fungicides for decreasing the seed-borne infection during germination and early seedling development of two safflower cultivars.

2. Materials and Methods

A laboratory experiment was conducted at the Seed Science and Technology Laboratory, Eskişehir Osmangazi University in 2020. Five fungicides, thiram (1 g kg^{-1} seed), maneb (1.5 g kg^{-1} seed), mancozeb (2 g kg^{-1} seed), metalaxyl (5 g kg^{-1} seed), and captan (2.5 g kg^{-1} seed) were applied to the seeds of safflower cultivars Olas and Linas. Seeds without fungicidal treatment were used as control. Two hundred seeds from each cultivar were firstly weighed, put into a falcon tube and a required amount of individual fungicide was poured over the seeds. The tube was tightly closed with a cover and shaken with vortex for 5 minutes for uniform coating of seeds with the fungicides (Islam et al., 2007). Untreated seeds were used as control.

Germination test was performed by the procedures of ISTA (2003) rules with two hundred (4×50) seeds of each safflower cultivar for each fungicide. Fifty seeds were inserted into two-layer filter papers wetted with 7 ml of the distilled water for each paper. After filter papers with seeds were rolled, they were placed into a sealed plastic bag to avoid water loss. The packages were incubated at 25°C in the dark and seed with 2 mm radicle was counted every 24 h for 10 d as germinated. To evaluate the speed of germination, mean germination time (MGT) was calculated according to ISTA (2003) rules. MGT= $\Sigma(Dn)/\Sigma n$, where, n is the seed number germinated on day D, and D is the number of days from the beginning of the germination test. On the 10th day, ten seedlings from each treatment were randomly selected to determine the seedling growth traits such as root length (RL), shoot length (SL), seedling fresh weight (SFW), and seedling dry weight (SDW). After the seedling fresh weight was directly weighed, the seedlings were transferred into an oven at 80°C for 24 hours for determination of dry weight (Ergin et al., 2021). Also, infection rate (IR) was determined by applying the following formula:

IR= (Number of seeds on which infection appears / Total number of seeds) × 100 (Arshad Javaid et al., 2006).

The experiment was established at two factors Completely Randomized Design (CRD) with 4 replicates. All the collected data were statically analyzed by using the MSTAT-C computer program. Means were compared with the LSD test to evaluate the differences among them (Düzgüneş et al. 1983).

3. Results and Discussion

The efficacy of fungicides on germination and seedling development is shown in Table 1. The difference between cultivars ($p<0.01$) for mean germination time, seedling length, seedling fresh weight, seedling dry weight and infection rate were statistically significant. Differences between safflower cultivars in terms of germination percentage and root length were not significant. There were significant differences among fungicides in germination percentage, mean germination time, root length, shoot length, and infection rate. Seedling fresh and dry weights were not affected by fungicides. Two-way interaction between cultivar and fungicide was significant for mean germination time, root length, shoot length and infection rate.

Fungicide treatments for seed-borne pathogens increased the germination percentage of safflower seeds. The germination percentage ranged from 86.8% in control to 93.8% in mancozeb, shown in Table 2. Similar results were reported by Khairmar et al. (2013) and Choudhary et al. (2013) who found that germination rates in control seeds were 76-84%, while it reached up to 91-95% in the seeds with fungicide applications. Mean germination time was shortened by fungicide treatments especially thiram and metalaxyl with 1.17 days. Among the fungicides, maneb and captan gave a longer time to germinate. Sundaresh et al. (1973) and Gawade et al. (2016) determined retardation in soybean germination in untreated seeds with fungicide and inhibition due to fungal infection (46%); however, seeds treated with thriam and mancozeb were completely free from fungal growth. The seeds treated with fungicides produced longer root length compared to untreated seeds of two cultivars. metalaxyl and thiram treatments gave the longest roots with 3.88 cm and 3.51 cm, respectively. Root length of cv. Olas was more prominently increased by treatment of metalaxyl and mancozeb. Shoot length was significantly enhanced when the seeds were treated with thiram and mancozeb in cv. Olas, maneb and mancozeb in cv. Linas. In general, shoot length in thiram, maneb and mancozeb showed slightly higher or similar to control seeds. Similarly, the longest seedling length in soybean was reached in metalaxyl-M + fludioxonil application (Costa et al. 2019). Choudhary et al. (2013) reported that thiram treatment gave longer roots than captan. The results are in line with the findings of Sultana and Ghaffar (2010) who reported that fungi adversely affect seedling growth, and that healthy seedling growth can be achieved with fungicidal applications. Seedling fresh weight was not changed by fungicide treatments and similar results were observed in all treatments except for cv. Olas were treated with metalaxyl, which produced the lowest fresh weight with 183 mg $plant^{-1}$. Heavier fresh and dry weight was determined in cv. Linas. No significant changes were observed in seedling dry weight among the fungicides. However, Solorzano and Malvick (2011) stated that the dry weight of corn seedlings had higher values when the seeds treated with fungicide mixtures were used.

Table 1
Analysis of variance on the investigated traits in safflower cultivars and fungicide treatments

VS	DF	Mean Square						
		GP	MGT	RL	SL	SFW	SDW	IR
Total	47	1126	2.44	32.2	7.80	4.21	0.09	22350
Cultivar (A)	1	30	0.08**	0.2	0.80**	0.64**	0.06**	2749**
Fungicide (B)	5	250*	0.35**	16.6**	2.77**	0.50	0.01	11233**
A × B	5	186	1.72**	8.3**	1.34**	0.54	0.01	5616**
Error	36	659	0.28	7.1	2.89	2.53	0.03	2751

*, **: significance level at p<0.05 and p<0.01, respectively. VS: Variation source, DF: Degrees of freedom, GP: Germination Percentage, MGT: Mean Germination Time, RL: Root Length, SL: Shoot Length, SFW: Seedling Fresh Weight, SDW: Seedling Dry Weight, IP: Infection Rate

Table 2
Germination percentage, mean germination time, and seedling growth parameters of two safflower cultivars treated with five fungicides

Factors	GP (%)	MGT (day)	RL (cm)	SL (cm)	SFW (mg plant^{-1})	SDW (mg plant^{-1})
Cultivar						
Olas	89.8	1.22^{b}	3.11^{a}	2.77^{a}	214^{b}	25.5^{b}*
Linas	91.3	1.30^{a}	2.98^{b}	2.51^{b}	237^{a}	32.6^{a}
Fungicide						
Control	86.8^{c}	1.25^{bc}	2.25^{d}	2.73^{ab}	228	29.8
Thiram	91.3^{ab}	1.17^{c}	3.51^{ab}	2.84^{a}	227	29.6
Maneb	89.3^{bc}	1.42^{a}	2.73^{c}	2.85^{a}	225	28.5
Mancozeb	93.8^{a}	1.24^{bc}	3.42^{b}	2.78^{a}	232	28.7
Metalaxyl	89.8^{abc}	1.17^{c}	3.88^{a}	2.19^{c}	204	28.3
Captan	92.5^{ab}	1.31^{b}	2.49^{cd}	2.45^{c}	235	29.7
Cutlivar×Fungicide						
Olas × Control	83.5	1.10^{bc}	1.79^{e}	2.88^{bc}	230	26.7
Olas × Thiram	92.0	1.04^{c}	3.79^{ab}	3.30^{a}	227	26.2
Olas × Maneb	88.0	1.79^{a}	2.78^{d}	2.89^{b}	212	25.1
Olas × Mancozeb	93.0	1.16^{bc}	4.10^{a}	2.95^{ab}	224	25.1
Olas × Metalaxyl	87.0	1.09^{bc}	4.19^{a}	2.18^{f}	183	24.7
Olas × Captan	95.0	1.13^{bc}	2.04^{e}	2.42^{def}	207	25.3
Linas × Control	90.0	1.40^{abc}	2.71^{d}	2.58^{b-f}	227	32.9
Linas × Thiram	90.5	1.30^{bc}	3.23^{bcd}	2.38^{ef}	227	32.9
Linas × Maneb	90.5	1.04^{c}	2.69^{d}	2.81^{bcd}	238	31.9
Linas × Mancozeb	94.5	1.33^{bc}	2.74^{d}	2.60^{b-e}	241	32.2
Linas × Metalaxyl	92.5	1.24^{bc}	3.56^{abc}	2.21^{ef}	225	31.8
Linas × Captan	90.0	1.49^{ab}	2.95^{cd}	2.48^{c-f}	263	34.0

*: Means followed by the same superscript letter(s) are not significant at p<0.05. GP: Germination percentage, MGT: Mean germination time, RL: Root length, SL: Shoot length, SFW: Seedling fresh weight, SDW: Seedling dry weight.

Infected seed rate is considered as the effectiveness of seed treatments by fungicides. Untreated control seeds showed that infection rate could be reached up to 100%, as in cv. Olas (Figure 1). However, fungicides inhibited the seed infection resulting from seed pathogens. The least infection rate was achieved in the application of thiram to seeds of cv. Olas. Our results confirmed the findings of Singh and Jha (2003) and Saroja (2012) who found thiram and carbendazim were the most effective agents inhibiting the growth of *Fusarium oxysporum* f.sp. *ciceri* at 1% concentration among seven fungicides. Also, in the study of Khairmar et al. (2013) was observed that the fungi in the seed mycoflora of different safflower cultivars decreased with thiram and thiram+carbendazim applications. Suresha et al. (2012) reported that the application of carbendazim+thiram significantly reduced the seed infection compared to captan, thiram, carbendazim and carbendazim+captan applications. Moreover, the beneficial effects of fungicidal seed treatments were informed by Munkvold and O'mara (2002) in maize, Habib et al. (2007) in eggplant, Akgül et al. (2011) in peanut, Ellis et al. (2011) in soybean, Dhanamanjuri et al. (2013) in chickpea and maize, Islam et al. (2015) in wheat and Addrah et al. (2020) in sunflower.

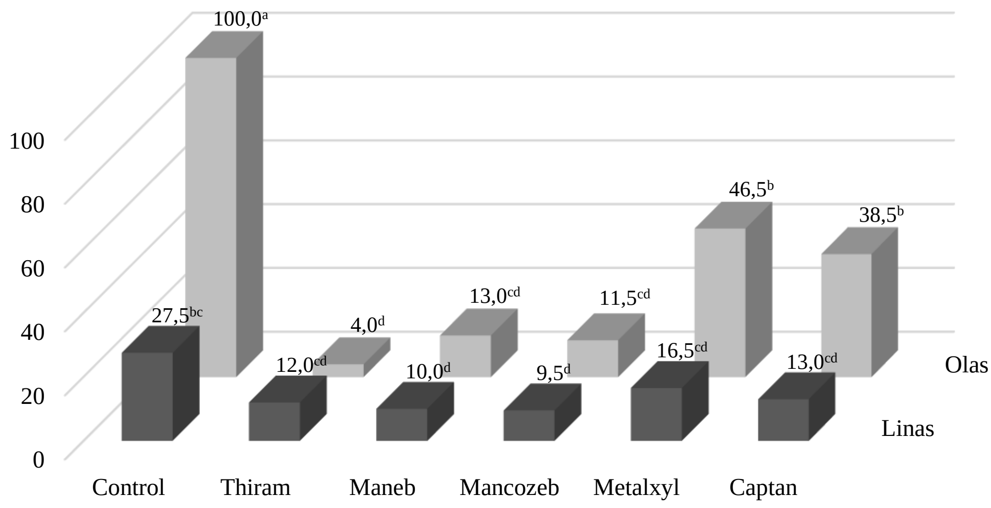

Figure 1
Infected seed rate of safflower cultivars treated with five fungicides during germination test.
*: Values on the each column followed by same letter(s) are not significant at $p<0.05$

In conclusion, germination test is routinely performed for seed certification processes and its results are commonly used for the required amount of seed per unit area; consequently, germination rate must be accurately determined. The main obstacle in germination tests in safflower is seed-borne pathogens which are more rapidly grown than germinating seeds. They multiply more rapidly in optimum germination conditions such as high humidity and temperature than seeds, and germination was restricted by infections. In our study, there were significant differences between safflower cultivars in terms of seed-borne pathogens. This difference results from genotypic variations because the seeds of two safflower cultivars were produced under Eskişehir conditions in 2020. But, detailed researches should be conducted by using several cultivars to make a precise decision. In addition, fungicides were effective to reduce seed-borne pathogens during the germination experiment. Pathogen-free healthy seeds are needed for desired plant populations and high yield. It is argued that seeds treatment with fungicides may favorably affect the emergence, stand establishment and consequently seed yield of safflower under field conditions. In conclusion, all the fungicides inhibited the seed-borne infections without adverse effects on germination rate and allowed to grow the healthy seedlings, and thiram, maneb and mancozeb should be advised for the seed treatments before germination test in safflower.

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Salicylic Acid Treatments for Extending Postharvest Quality of Tomatoes Maintained at Different Storage Temperatures

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ABSTRACT

Salicylic acid (SA) is known to be an effective tool on extending the postharvest quality of horticultural commodities by preventing synthesis and movement of ethylene. Thus, the present study was established to study the effect of different dozes of SA treatments (0.5 mM, 1.0 mM and 2.0 mM) on extending postharvest quality of pink maturity tomatoes maintained at two different storage conditions (5 °C with 90% relative humidity and 20 °C with 65% relative humidity). SA treatment at all doses significantly retarded weight loss at both storage conditions. SA treated tomatoes were firmer, higher in titratable acidity, and exhibited less biochemical changes than the control fruit at the end of storage. Among the applied dozes, SA at 2 mM can be recommended as it was pioneering for most of the parameters analyzed during cold storage at both 5 °C for 20 d and at 20 °C for 10 d. SA treatment may be recommended as an environmental friendly, healthy and sustainable method for extending postharvest quality of tomatoes cold storage and shelf life, without significant adverse effect on produces.

1. Introduction

Tomato is one of the most important vegetable crops grown in Turkey. According to 2018 statistical data, 12.8 million tons of tomatoes are produced in Turkey, which corresponds to approx. 7% of the total world production (180 million tons) (Anonymous 2021). Tomato fruits are an important vegetable crops and are among major contributor of carotenoids (especially lycopene), phenolics, vitamin C and small amounts of vitamin E in daily diets (Gautier et al. 2008).

Tomatoes are climacteric fruits and their ripening is highly depended on ethylene action (Mostofi et al. 2003; Guillen et al. 2007). The rapid ripening of fruit after harvest limits storability and is a concern during transportation and marketing. Ethylene synthesis and action in tomatoes can be affected by low temperature storage, controlled or modified atmosphere and application of ethylene antagonists (Feng et al. 2004; Sabir and Agar 2011).

Salicylic acid (SA), a phenolic compound found in a wide range of plant species, exhibits a high potential in controlling the postharvest losses of horticultural crops. Postharvest SA treatments decrease the ethylene biosynthesis and action, induce the resistance towards disease, prevent oxidative stresses, support the fruit tolerance to chilling injury, decrease respiration rate, delay ripening and senescence, slow down the activity of cell wall degrading enzymes and maintain the crop firmness (Asghari and Aghdam 2010).

Application of exogenous SA at non-toxic concentrations to fruit has been shown to inhibit respiration and ethylene production of plum (Luo et al. 2011) and apricot (Erbaş et al. 2015). Postharvest exogenous application of SA, delayed over-ripening in fruits like kiwifruit (Zhang et al. 2003), sweet cherries (Valero et al, 2011) and peach (Sabir et al. 2019). Furthermore, treatments with SA alleviated chilling injury of tomatoes (Aghdam et al. 2012) and pomegranates (Sayyari 2011).

The objective of the present study was to evaluate the effect of different concentrations of SA (0.5 mM, 1.0 mM and 2.0 mM) and storage temperatures (20 and 5 °C) on extending the postharvest quality attributes of tomatoes (*Lycopersicon esculentum* Mill.) during storage.

2. Materials and Methods

Tomatoes (*Lycopersicon esculentum* Mill.) *cv.* ‘Durinta’ were harvested from commercial field in Cumra, Turkey at pink maturity stage using the United States Department of Agriculture tomato ripeness color classification chart (USDA 1991) and immediately

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transferred to the laboratory of the Department of Horticulture at Selcuk University. Afterwards, fruits were selected for unity and freedom from defects and blemishes, tomatoes were randomly divided into four equal lots. First lot was evaluated as a control group untreated while three lots were assigned to different concentrations of SA (0.5 mM, 1.0 mM and 2.0 mM) treatments. Each group further divided into two lots for different storage temperatures (5 and 20 °C).

SA (Sigma- Aldrich 69-72-7) treatments were performed by dipping fruits in 5 L of solution for 5 min at ambient temperature (22°C) with the addition of 0.01% Tween 20 (Merck 9005-64-5) surfactant, and then fruits were left to dry at room temperature. Treated and untreated fruits were stored at 5 °C (cold storage with 90% relative humidity) for 20 d or 20 °C (ambient temperature with 65% relative humidity) for 10 d in open boxes. Fruit quality attributes was evaluated after 0, 2, 4, 7 or 10 d at ambient temperature and 0, 5, 10, 15 or 20 d at cold storage.

The weight loss (%) during postharvest storage was determined by periodical weighing, and calculated by dividing the weight change during storage by the initial weight:

Weight loss (%) = [(Wi – Ws)/Wi] × 100, where Wi = initial weight and Ws = weight at examined time.

Fruit firmness was measured using a digital penetrometer (fruit pressure tester, model 53205; TR, Forlì, Italy) with an 8 mm probe. Ten fruits in each replication were pressed at opposite sides of their equatorial axes. Results were expressed as Newton (N).

Skin color of ten tomatoes per treatment was analyzed using a colorimeter (Minolta® CR-400) to obtain the following variables from two equatorial points of fruits: L*, a*, b*. Results were calculated as hue angle (h°) using equations described by McGuire (1992).

Tomato juice squeezed from fruit was analyzed for total soluble solid content (SSC) using a refractometer (Atago, Tokyo, Japan) and results were expressed as %. Titratable acidity (TA) was determined by titrating 5 mL of juice using 0.1 N NaOH to pH 8.1, and expressed as % citric acid. The ratio between SSC and TA was also calculated as ripening index (RI).

Lycopene content of tomatoes was performed as previously described by Sharma and Maguer (1996); Rao et al. (1998) with slight modifications. For lycopene analysis, pericarp tissue of tomatoes was blended with a warring blender for 1 min. One gram of homogeneous tissue and 50 mL hexane:ethanol:acetone (2:1:1, v/v) were shaken for 30 min. After shaking, 10 mL of distilled water were added and shaken for 5 min again. The solution was then placed in a separator funnel and, after phase separation, the upper phase was collected. The extract was filtered via Whatman No. 42 filter paper and lycopene concentration was determined by measuring the absorbance of the solution at 502 nm using a UV-visible spectrophotometer. Results were expressed as mg kg^{-1} fresh fruit weight.

The experiment was a completely randomized design with three replications and each replication contained 15 fruits. Data from analyzed parameters were subjected to analysis of variance separately. Sources of variation were treatment, storage time and their interaction. Means were compared by Student’s t-test at $P \leq 0.05$, using JMP statistical software version 5.1 (SAS Institute Inc., Cary, NC, USA).

3. Results and Discussion

For both storage conditions, the percentage of weight loss increased during prolonged storage for control and all SA treatments (figure 1) while the effect of SA treatments on weight loss was found statistically significant. At the end of the cold storage, the greatest loss in weight occurred in non-treated control tomatoes (2.06%), while the lowest value was obtained from 1.0 mM SA (1.71%). As for the tomatoes stored at 20 °C, similar weight loss course was seen with that of the cold storage findings. Accordingly, all the treatments significantly restricted the loss in weight during the storage at 20 °C, with more pronounced effect following 4^{th} d. Among them, SA treatments at 1.0 mM resulted in the lowest loss in weight with the value 4.43%, which was followed by 0.5 mM SA (3.50%). On the other hand, the weight loss in 2 mM SA tomatoes was as high as 3.78%, resulting from a progressive increment in moisture loss from produces along with the storage at ambient temperature. The weight loss is known to be the major determinant of storage life and quality of fresh commodities (Sabir and Agar 2011) and mainly regulated by respiration, transpiration and metabolic activities in fruits. SA has been reported to close stomata which results in suppressed respiration rate and minimized weight loss of fruits (Tareen et al. 2012). According to the more recent studies, postharvest SA treatment was effective in delayed the weight loss in various horticultural products such as apple (Sabir et al. 2013), plum (Davarynejad et al. 2015), apricot (Erbaş et al. 2015) and peach (Tareen et al. 2012). Thus, the results of this study suggest that SA might have reduced respiration and transpiration which concomitantly delayed weight loss. As illustrated in figure 2, firmness of the fruits gradually decreased during the prolonged storage in both storage conditions. However, all SA treatments significantly maintained the fruit firmness in comparison to control fruits. Initial firmness value of tomatoes were 41.7 N. At the end of the cold storage period, the highest firmness value was obtained from 2.0 mM SA treatment (34.5 N), followed by 1.0 and 0.5 mM SA treatments (29.4 and 27.5 N, respectively). On the other hand, fruits of control treatment showed the lowest firmness value (26.6 N). Firmness of the tomatoes also underwent a significant decrease during their storage at 20 °C. At the end of the experiment, firmness values were 27.7 N, 25.8 N, 24.5 N and 22.9 N for 2.0 mM SA, 1.0 mM SA, 0.5 mM SA and control, respectively. Results indicated 2.0 mM SA treatment significantly delayed the softening compared to control. Similar results were also obtained by Awad (2013) who reported that 0.5, 1.0 and 1.5 mM SA significantly inhibited the decrease of firmness in peach fruits.

Figure 1
Effects of SA on weight loss (%) of tomato during cold storage at 5 °C and ambient temperature storage at 20 °C. Each bar represents the mean of three replicates of 5 fruits each. Vertical bars represent the standard deviation of that mean.

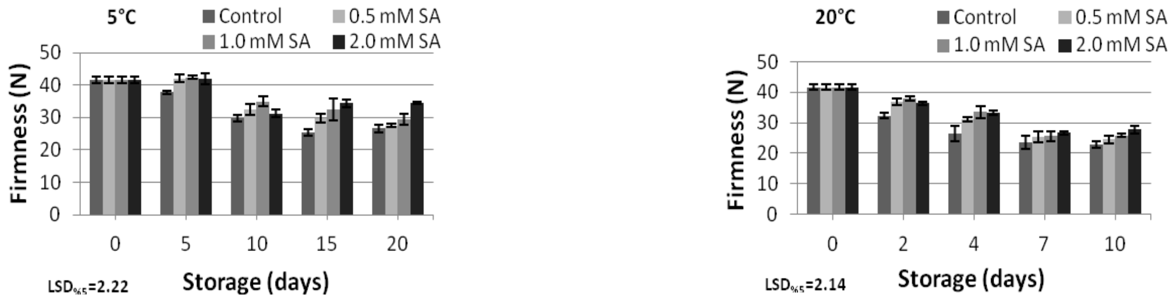

Figure 2
Effects of SA on firmness (N) of tomato during cold storage at 5 °C and ambient temperature storage at 20 °C. Each data point represents the mean of three replicate samples. Vertical bars represent the standard deviation of that mean.

Changes in the fruit skin color related values during cold and ambient storage conditions were shown in figure 3. Decrease in the fruit skin hue angle value was recorded with the prolonged storage time in both storage condition, but the differences between the treatments were statistically insignificant. At harvest, h° value of fruit skin was 49.3°. At the end of the cold storage, the highest h° value was obtained from the fruits of the control fruits (48.1°), while the lowest value was measured in the 2.0 mM SA treated fruits (46.1°). h° value of the tomatoes also decreased along with the storage at 20 °C similar to cold storage findings. Finally, h° values of fruit skin ranged from 43.8° (2.0 mM SA) to 42.5° (control). Tomato color is greatly correlated with lycopene content, and as the fruit develops from the mature green stage to the red stage, lycopene concentration increases significantly (Nunes 2008).

Figure 3
Effects of SA on skin color (h°) of tomato during cold storage at 5 °C and ambient temperature storage at 20 °C. Each data point represents the mean of three replicate samples. Vertical bars represent the standard deviation of that mean.

In general, SSC underwent a slight but insignificant increase through the storage (table 1). At the harvest, SSC contents of fruits were 4.70%. These values increased during the storage regardless from treatments. At the end of the storage, the highest SSC was observed in control (5.03%), while the least value was recorded in 0.5 mM SA (4.53%). Some researchers reported that single use of SA treatment had no effect on SSC of several fruits like grape (Ranjbaran et al. 2011) and persimmon (Khademi et al. 2012).

TA values tended to reduce during the cold storage across the applications. TA was 0.517% at harvest while at the end of the storage ranged from 0.410% (control) to 0.473% (2.0 mM SA). During the ambient storage conditions, TA also decreased during the storage. The highest TA was observed in 2.0 mM SA (0.420%), followed by 1.0 mM SA (0.413%) and control (0.397%) while the least value was recorded in 0.5 mM SA (0.373%) at 10 days (table 2). 2.0 mM SA treatment significantly prevented TEA decline in both storage conditions. These observations were well adjusted to the findings of Sayyari et al. (2009) on pomegranates, Davarynejad et al. (2015) on plum and Bal (2012) on cherry.

Table 1
Effects of SA on SSC, TEA, SSC/TA and lycopene of tomato during cold storage (5 °C).

Treatments	Storage (days)				
	0	5	10	15	20
SSC					
Control	4.70±0.17	4.93±0.12	4.73±0.12	4.97±0.06	5.03±0.06
0.5 mM SA		4.93±0.42	4.67±0.12	4.50±0.35	4.53±0.35
1.0 mM SA		5.00±0.20	4.67±0.23	4.50±0.10	4.77±0.12
2.0 mM SA		5.00±0.00	4.93±0.12	4.53±0.25	4.83±0.12
TA					
Control	0.517±0.031 a	0.422±0.012 fgh	0.420±0.010 fgh	0.405±0.012 h	0.410±0.010 gh
0.5 mM SA		0.500±0.020 abc	0.437±0.032 d-h	0.450±0.026 def	0.442±0.023 d-g
1.0 mM SA		0.508±0.035 ab	0.430±0.017 e-h	0.428±0.010 fgh	0.455±0.012 def
2.0 mM SA		0.472±0.010 bcd	0.467±0.012 cde	0.453±0.015 def	0.473±0.032 bcd
SSC/TA					
Control	9.10±0.084 f	11.71±0.08 abc	11.28±0.40 bcd	12.27±0.32 ab	12.30±0.36 a
0.5 mM SA		9.84±0.42 ef	10.71±0.78 de	9.98±0.17 ef	10.30±1.18 de
1.0 mM SA		9.85±0.31 ef	10.83±0.18 cde	10.52±0.45 de	10.48±0.37 de
2.0 mM SA		10.59±0.20 de	10.59±0.45 de	10.01±0.59 ef	10.27±0.85 e
Lycopene					
Control	28.85±1.02 d-g	27.91±0.88 d-g	29.41±1.06 cde	32.58±1.24 b	35.20±3.08 a
0.5 mM SA		27.39±1.29 efg	29.99±0.99 cd	33.66±1.62 ab	35.44±1.73 a
1.0 mM SA		26.83±0.74 fg	29.20±0.93 def	29.93±1.28 cd	31.82±1.90 bc
2.0 mM SA		26.48±1.32 g	26.94±1.21 fg	28.86±2.13 d-g	28.79±1.91 d-g

LSD for SSC: N.S., TA: 0.04, SSC/TA: 0.99, Lycopene: 2.43

Table 2
Effects of SA on SSC, TA, SSC/TA and lycopene of tomato during ambient storage (20 °C).

Treatments	Storage (days)				
	0	2	4	7	10
SSC					
Control	4.70±0.17	4.07±0.12	4.73±0.12	4.06±0.03	4.53±0.23
0.5 mM SA		4.27±0.06	4.67±0.12	4.06±0.03	4.47±0.12
1.0 mM SA		4.23±0.06	4.93±0.12	4.08±0.01	4.67±0.12
2.0 mM SA		4.33±0.06	4.67±0.31	4.40±0.17	4.67±0.12
TA					
Control	0.517±0.031 a	0.483±0.015 bc	0.442±0.003 ef	0.399±0.012 gh	0.398±0.006 gh
0.5 mM SA		0.453±0.012 de	0.433±0.015 ef	0.430±0.017 ef	0.376±0.021 h
1.0 mM SA		0.436±0.021 ef	0.455±0.023 cde	0.427±0.015 efg	0.413±0.015 fg
2.0 mM SA		0.493±0.006 ab	0.476±0.015 bcd	0.416±0.012 fg	0.420±0.017 fg
SSC/TA					
Control	9.10±0.084 ghi	8.40±0.13 i	10.72±0.30 bcd	10.18±0.38 c-f	11.41±0.77 ab
0.5 mM SA		9.43±0.33 fgh	10.79±0.42 bcd	9.43±0.35 fgh	11.91±0.59 a
1.0 mM SA		9.73±0.62 e-h	10.85±0.40 bc	9.55±0.24 fgh	11.32±0.58 ab
2.0 mM SA		8.77±0.07 hi	9.82±1.01 d-g	10.59±0.65 b-e	11.12±0.12 abc
Lycopene					
Control	28.85±1.02 i	35.31±1.32 d	34.87±1.06 de	34.57±0.73 def	47.18±2.31 a
0.5 mM SA		32.62±2.23 gh	28.69±0.88 i	29.28±0.85 i	39.56±0.19 b
1.0 mM SA		33.71±0.69 d-g	32.18±1.23 gh	34.77±1.23 def	39.04±0.13 bc
2.0 mM SA		31.68±0.47 h	32.98±0.95 fgh	33.28±0.48 e-h	37.19±1.20 c

LSD for SSC: N.S., TA: 0.03, SSC/TA: 0.97, Lycopene: 1.86

During storage, SSC/TA values tended to increase in various levels according to the treatments in both storage conditions. SSC/TA ratio of tomatoes 9.10 at harvest. At the end of the 20 d cold storage duration, the highest SSC/TA value was determined in control fruits (12.30), while the lowest ratio was calculated in 2.0 mM SA treated fruits (10.27). SSC/TA of the tomatoes markedly increased along with the storage at 20 °C similar to cold storage findings. After 10 days of storage at 20 °C, SS/TA ratios were 11.91, 11.41, 11.32 and 11.12 for 0.5 mM SA, control, 1.0 mM SA and 2.0 mM SA, respectively. During the storage period, it was determined that postharvest 2.0 mM treatments effectively delayed the increase in SSC/TA value compared to control.

Changes in lycopene content of tomatoes during the cold storage at 5 °C were presented in table 1. Initial lycopene content of tomatoes was 28.85 mg kg^{-1} and underwent a remarkable increase due to ripening advancement, with the greatest change in control along with the prolonged storage. 2.0 mM SA treatment significantly delayed the initiation of lycopene synthesis during cold storage. At the end of storage, the highest lycopene values were determined in control fruits (35.20 mg kg^{-1}), while the lowest lycopene amount was detected in 2.0 mM SA treated fruits (28.79 mg kg^{-1}). During ambient storage conditions, lycopene content increase with prolonged storage period. In control and SA treatments, this increase reached maximum level in 10 days. Lycopene values varied from 37.19 mg kg^{-1} (2 mM SA) to 47.18 mg kg^{-1} (control) at the end of storage.

4. Conclusion

The storability and shelf life of tomatoes are limited due to their perishable texture and accelerated ripening after harvest. Salicylic acid (SA), known to be an effective tool on extending the postharvest quality of horticultural commodities by preventing synthesis and movement of ethylene, was tested at various doses (0.5 mM, 1.0 mM and 2.0 mM) for effectiveness on postharvest quality maintenance of tomatoes stored at two different storage conditions (5 °C with 90% relative humidity and 20 °C with 65% relative humidity). SA treatment at all doses remarkably retarded weight loss at both storage conditions. Changes in firmness and many other biochemical features were retarded by SA. Among the applied dozes, SA at 2 mM can be recommended as it was pioneering for most of the parameters analyzed during cold storage at both 5 °C for 20 d and at 20 °C for 10 d. SA treatment may be recommended as an environmental friendly, healthy and sustainable method for extending postharvest quality of tomatoes cold storage and shelf life, without significant adverse effect on produces.

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The Species and Intensities of Weed Seeds Obtained from Wheat Flour Mill Plants in Turkey**

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ABSTRACT

Wheat production is more than 10% is in first place with potential in Konya plain of Turkey. Weed seeds mixed crop seeds cause quality and yield losses on production. This research was carried out to determine the species, intensity and frequency of weed seeds obtained from flour mill plants operating in Konya. Samples were taken from the 15 flour mill plants with working high capacity in the region. Identification of the weed seeds species in the sample was made. Comparison was made with live materials and reference documents by examining the seeds under a binocular while diagnosis of species. Also, the intensity and frequency of the species contaminated in wheat were determined. As a result of the study, 79 weed seed species belonging to 19 different families were identified. The species of families the most inclusive were Poaceae with 14 species and Leguminosae with 13 species. In order to determine intensity and frequency of species, weed seeds counted by hand, weighed in scale were recorded in laboratory. The highest weed seeds intensity as number and weight among the species were determined *Galium tricornutum* (rough bedstraw) with 16.16% and *Aegilops cylindrica* (jointed goatgrass) with 21.22% respectively. About the frequency of species, the most frequent species was *Convolvulus arvensis* (field bindweed) with 100%.

Introduction

Wheat is a crop plant which is essential for whole humanity. Many products are made from wheat today. Wheat means being full. The role and importance of flour obtained from wheat, bread and other products made from flour in human life is far too great. Wheat is a strategic product that is widely grown in the world, plays an important role in the nutrition and commercial life of many countries, is the most produced among crops and is used in human nutrition (Arısoy and Oğuz 2005).

In terms of world wheat production, China (133.6 million tons) ranks first. This country is followed by India (103.6 million tons), Russia (74.5 million tons) and USA (52.3 million tons). Turkey, on the other hand, ranks 11th in world wheat production with a production of 19 million tons (Anonymous 2019). It has an agricultural area of approximately 23 million ha in Turkey. Wheat is produced in approximately 7 million hectares of this area. Konya province ranks first in Turkey in terms of cultivation area (6.2 million decares) and production (1.92 million tons) (Anonymous 2020).

Today world population is increasing rapidly. Uncontrolled population growth is the most important fact gradually revealing the danger of hunger. Population growth increasing every day causes wheat yield to fall short. One of the most significant agricultural factors restricting wheat production is weeds because weeds cause decreases in the quality of wheat crop, and they also reduce yield of wheat produced in unit area. Weeds are the natural plants of agricultural and nonagricultural areas. Economically weeds mean, they are the plants which appear in and out of cultivated areas and do more harm than good for cultivated plants.

Weeds compete with crop plants for water, nutrients, space and light. These factors sometimes act alone and sometimes together. Because of some characteristics, they often have superior competitive power against crop plants. If measures are not taken, weeds can cause 20-40 % yield loss depending on the species of crop plants (Güncan 1982; Güncan and Karaca 2018; Zimdahl 2018; Güncan, 2019).

By contaminating with crop plant seeds, weed seeds decrease the nutritional value and spoil seed quality (Güncan 2002). In the research conducted in Turkey, it was determined that contamination rate of weed seeds

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in wheat product which was not passed through the selector was at an average of 1.17% numerically, at an average of 0.412% as weight (Güncan and Boyraz 2001). According to the findings, when wheat production in our country is accepted as 20 million tons, it is necessary to consider that 8.240 tons of weed seeds are consumed each year and sown again into the fields in case of not cleaning wheat product. The same researchers state that if the mentioned wheat is sown without cleaning, 5.600 weed seeds perdecare will be carried into the field just through the contaminated wheat seeds. In other words, 5-6 weed seeds per m² are carried through the mentioned way and this might cause a significant level of weed contamination. Tursun et al (2006) reported that the most common weed seeds contaminated with wheat were *Sinapis arvensis, Hordeum vulgare, Lolium temulentum, Boreava orientalis* and *G. tricornutum* respectively, and *H. vulgare, B. orientalis, S. arvensis*, and *L. temulentum* by weight, respectively in Kahramanmaraş. Karaca and Güncan (2009), carried out a study to determine the contamination ratio of *Secale cereale* to wheat product. It was determined that wild rye seed was contaminated in wheat product with an average of 1.1536% numerically and 0.9522% by weight in Konya province.

Gökalp and Üremiş (2015) determined that the most common weed seeds contaminated numerically with wheat were *Avena sterilis*, *S. arvensis* and *G. tricornutum* and *A. sterilis, Silybum marianum* and *Hordeum murinum* by weight respectively in Mardin province. Baş et al. (2016), found that in their study to detect weed seeds contaminated with wheat crops, *Agrostemma githago* and *Caucalis latifolia* were numerically very dense. They found that *Adonis* sp., *Ranunculus arvensis* and *G. tricornutum* were heavily contaminated in the Eastern Black Sea Region. Pala et al. (2018) determined that the weed seeds were most intensely contaminated into the harvested wheat product belonged to the Poaceae family with 13 species. It was determined that the most common species were *Avena fatua* and *A. sterilis* in Diyarbakır province. In the research of Bozkurt and Tursun (2018) found that numerically, *S. arvensis, Cephalaria syriaca* and *Polygonum aviculare* were the most common weed seeds respectively. According to the weight ratio, the most common species were found as *Caucalis daucoides*, *C. syriaca* and *Galium aparine* in Muş province. In the studies conducted in Balıkesir and Çanakkale, *S. arvensis* and *G. aparine* were determined as the most frequently contaminated weed seeds numerically, while *H. vulgare* was the most contaminated species in both provinces by weight (Kaçan and Tursun 2019).

In a study conducted between the years of 1974 and 1990 in Germany, it was reported that weed seed contamination average rate of grains was 0.5 %, and this contamination increased to 2% in wheat (Fuchs and Voit, 1992). Similarly, in another study conducted in Spain, it was determined that weed seeds contaminated in grains dramatically (Trigo et al. 1991). Nikham et al. (2002) were carried out a survey in the Victoria in Australia. Mainly wheat and barley seeds were collected. The main weed seeds in cereal samples were annual ryegrass (*Lolium multiflorum*), wild oats (*Avena* spp.), silver grass (*Vulpia bromoides* L.), lesser canary grass (*Phalaris minor*), brome grass (*Bromus* spp.) and paradoxa grass (*Phalaris paradoxa*).

Çetik (1985) reported that there are too many weeds growing in the cultivation areas of forage plants and in pasture-meadow areas in the Central Anatolia Region. The researcher stated that weed seeds quickly germinate under appropriate conditions, they might remain dormant for a long time under inappropriate conditions. It is stated that many of these weeds are eaten by animals. Güncan and Karaca (2018), on the other hand, states that some weeds are a good feed source for animals both in summer and winter, some of them are not eaten by animals when they are fresh in summer because of bitter substances that they contain, but when they are dried, their bitterness disappears and they are eaten hungrily by animals.

The aim of this study, to determine which weed species are contaminated with wheat by using the samples taken from under-sieve, purifier, washing and trieur parts in flour mill plants and the rate of contamination. It is known that weed seeds obtained from various sieve systems in flour mill plants are used as feed in animal husbandry in Turkey. However, a large number and species of weed seeds can be transported to agricultural fields with animal manures. No study has been found on this subject. Therefore, the species and intensities of weed seeds that can be transported to agricultural areas with animal manures will be revealed.

2. Materials and Methods

The material of this study conducted in 2012-2013 consists of weed seeds obtained from flour mill plants in Konya, weed seed collection, precision scale, binocular and diagnostic books.

Determining weed seeds and their intensities:

In the research, samples were taken from 15 flour mills with high operating capability in Konya province. These are the samples which were processed through different sieving systems such as sieve, purifier, washing and trieur parts of factory. Since the materials from which the seeds are obtained are of different weights and volumes, the samples were extracted from materials until 100 g of weed seeds were obtained per flour mill plant. One hundred grams of weed seeds obtained from each flour mill plant were separated according to their genus and species.

In the second phase of the research, weed seeds collected from samples were diagnosed. Following this process, weed seeds were counted by hand in the herbology laboratory and their weights were recorded after weighing on a precision scale. Besides, intensity (as number and weight) and frequency of occurrence were calculated for each weed seed in 1.500 g of samples collected from 15 flour mill plants. In the research, % intensity (as number and weight) and frequency of occurrence were calculated according to the following formula (Odum 1971; Uludağ 1993; Baş et al .2016).

Intensity (%)=T/nx100

Frequency (%)=M/nx100

T= Total number of weed seed in the collected sample

M= Number of samples in which weed species was encountered

n= Number of samples

Weight (%)=A/Bx100

Number (%)=C/Dx100

A= Weight of selected weed seed

B=Seed weight in total

C=Number of selected weed seed

D=Number of seeds in total

To name the weeds in Turkish, the book entitled “Türkiye’nin Yabancı Otları” by Uluğ et al (1993) and the dictionary entitled “Bitki Terimleri” by Akalın (1952) were used. For the morphological and biological characteristics of the plants, the book entitled “Türkiye’nin Çayır-Mera Bitkileri” was employed. While diagnosing weed seeds, the weed seed collection prepared in previous years by Academic Member Prof. Dr. Ahmet GÜNCAN from Selcuk University, Faculty of Agriculture, Department of Plant Protection was used. In addition, Bischof’s (1978) book entitled “Common Weeds from Iran, Turkey, the Near East and North Africa” on weed diagnosis was used. Weed seeds that could not be identified in the study were stated as others.

3. Results and Discussion

In the research, 79 weed species belonging to 19 families were determined and identified. Among these identified species, Fabaceae which included 15 species and Poaceae which included 12 species were the families which had the most species.

According to the results obtained in the research, the weed seed having the highest number was *G. tricornutum* (Fam: Rubiaceae) with the number of 39.539 *P. aviculare* and *Polygonum convolvulus* (Fam: Polygonaceae) follow this species with the numbers of 38.313 and 37.736 respectively. The fewest number of weed seed is 1 and it belongs to *Trifolium alexandrinum, Medicago hispida, Medicago sativa, Nicis benedictus, Onopordum caucalis, Patroselinum* sp. The heaviest weed seed was *Aegilops cylindrica* (Fam: Poaceae) with 289,077 g *A. fatua* (Fam: Poaceae) and *P. convolvulus* (Fam: Polygonaceae) follow it with 150,764 g and 133,449 g respectively. The weed seed having the lowest weight is *Trifolium alexandrinum* (Table 1).

Table 1
Number and weight of weed seeds determined from the wheat flour mill plants in Konya Provinces

Weed Species/Families	*Seed (number)	*Seed Weight (g)
Apiaceae (Umbelliferae)		
Bifora radians Bieb.	693	8.184
Bifora testiculata (L.) sprengex Schultes	535	5.808
Caucalis daucoides L.	7	0.307
Caucalis latifolia L.	75	1.386
Caucalis orientalis	6	0.002
Patroselinum sp.	1	0.001
Asteraceae (Compositae)		
Carthamus persicus Willd.	91	0.18
Centaurea deprassa Bieb.	560	6.359
Centaurea melitensis	5	0.02
Centaurea repens L.	102	0.087
Centaurea solstitialis L.	2	0.005
Cirsium lanceolatum (L.) Scop.	14	0.129
Onopordum acanthium L.	350	2.274
Onopondum caucalis	1	0.006
Boraginaceae		
Anchusa italica Retz.	36	0.807
Borogo sp.	24	0.179
Lithospermum arvense L.	5.954	18.728
Lycopsis orientalis	9	0.041
Brassicaceae (Cruciferae)		
Boreava orientalis Jaub and Spach	433	21.654
Euclidium syriacum (L.) R.Br.	140	0.714
Neslia apiculata Fisch.	872	4.142
Rapistrum rugosum (L.) All.	966	7.952
Thilapsi arvense L.	4.737	4.46
Caryophyllaceae		
Agrostemma githago L.	933	11.507
Gypsophila sp.	23.689	58.836
Silene caucalis	627	0.953
Silene conoidea L.	7.299	16.954
Vaccaria pyramidata Medik	13.566	37.4
Chenopodiaceae		
Beta lomatogona Fisch and Mey.	31	0.247
Chenopodium sp.	6.078	5.342

Table 1(Continue)
Number and weight of weed seeds determined from the wheat flour mill plants in Konya Provinces

Convolvulaceae		
Convolvulus arvensis L.	9641	94.612
Dipsacaceae		
Cephalaria aristata (C.) Koch	682	2.962
Cephalaria syriaca (L.) Schrad.	46	0.45
Fabaceae (Leguminosae)		
Lathyrus aphaca L.	67	0.893
Lathyrus sp.	213	0.429
Medicago hispida Gaertn.	1	0.038
*Medicago rigidula (*L.) All.	3	0.155
Medicago sativa L.	1	**0
Melilotus officinalis (L.) Desr.	2.627	4.626
Onobrichis sativa Lam.	4	0.47
Trifolium alexandrinum	1	**0
Vicia fabae	37	4.669
Vicia pannonica	495	21.7
Vicia peregrina L.	8	0.226
Vicia sativa L.	246	14.355
Vicia villosa Roth.	60	1.433
Labiatae (Lamiaceae)		
Marrubium peregrinum	298	0.426
Salvia sclarea L.	24	0.077
Lilliaceae		
Allium sp.	8	0.038
Ornithogalum narbonense L.	5	0.039
Malvaceae		
Althaea sp.	14	0.97
Malva parviflora L.	6	0.048
Poaceae (Gramineae)		
Aegilops cylindrica Host.	6.997	289.077
Alopecurus myosuroides Huds.	221	0.358
Avena fatua L.	7.050	150.764
Avena sativa	1.354	32.3
Avena sterilis ssp. *Ludoviciana*	29	0.363
Lolium multiflorum Lam.	1.335	7.539
Lolium temulentum L.	847	7.694
Panicum italicum	3.244	13.023
Phalaris minor Retz.	4.890	11.112
Poa bulbosa L.	560	1.121
Secale cereale L.	2.535	95.892
Setaria lutescens (Weigel ex Stuntz) F. T. Hubbard	4.058	12.791
Sorghum halepense (L.) Pers.	38	0.144
Sorghum sp.	193	3.797
Polygonaceae		
Polygonum aviculare L.	38.313	91.329
Polygonum convolvulus L.	37.736	133.449
Rumex crispus L.	96	0.125
Ranunculaceae		
Adonis aestivalis L.	4	0.039
Adonis flammea Jacq.	3	0.019
Consalida orientalis (Gay) Schröd.	1.264	1.587
Ranunculus arvensis L.	499	6.064
Resedaceae		
Reseda lutea L.	2.894	2.968
Rubiaceae		
Galium aparine L.	7.885	24.8
Galium tricornutum Dandy.	39.539	111.679
Scrophulariaceae		
Veronica triphyllos L.	391	0.436
Solanaceae		
Hyoscyamus niger L.	238	0.226
Diğer		
Nicis benedictus	1	0.025
Others	39.475	140.024
TOTAL	284.025	1.500

* In the 1.500 g sample
** Quite close to 0

When Table 2 is examined, numerically the most intensive species according to the % calculations were *G. tricornutum* with 16.17 %, *P. aviculare* with 15.67 % and *Polygonum concolvulus* with 15.43 % respectively. While *A. cylindrica* had the highest intensity with 21.22% as weight, *A. fatua* with 11.07% and *P. convolvulus* with 9.80% followed them. When frequency of occurrence is taken in to consideration, it is seen that *Convolvulus arvensis* with the rate of 100 % was present in all samples. This species was followed by *Lithospermum arvense, Gysophila* sp., *P. aviculare, S. cereale* and *Vaccaria pyramidata* with the rate of 93,33%.

Similarly, Tursun et al. (2006), Gökalp and Üremiş (2015) and Baş et al. (2016) found *G. tricornutum* and *A. sterilis* as the most contaminated species the wheat crop in their studies. Also Bozkurt and Tursun (2018) found that numerically, *P. aviculare* were the most common weed seeds respectively.

Table 2
Number (%), weight (%) and frequency (%) of weed seeds obtained from the wheat flour mill plants in Konya Province

Weed Species	Seed Number (%)	Seed Weight (%)	Frequency (%)
Adonis aestivalis	0.0016	0.0028	13.3333
Adonis flammea	0.0012	0.0266	13.3333
Aegilops cylindrica	2.8613	21.2244	86.6666
Agrostemma githago	0.3815	0.8448	33.3333
Allium sp.	0.0032	0.0026	13.3333
Alopecurus myosuroides	0.0903	0.0262	46.6666
Althaea sp.	0.0057	0.0071	6.6666
Anchusa italica	0.0147	0.0592	33.3333
Avena fatua	2.8829	11.0693	86.6666
Avena sativa	0.5536	2.3715	73.3333
Avena sterilis ssp. *Ludoviciana*	0.0081	0.0266	13.3333
Beta lomatogona	0.0126	0.8158	20
Bifora radians	0.2833	0.6008	53.3333
Bifora testiculata	0.2187	0.4264	13.3333
Boreava orientalis	0.1770	1.5898	53.3333
Borogo sp.	0.0098	0.0131	6.6666
Carthamus persicus	0.0372	0.0132	40
Caucalis daucoides	0.0028	0.0254	33.3333
Caucalis latifolia	0.0306	0.1017	60
Caucalis orientalis	0.0024	0.0001	6.6666
Centaurea deprassa	0.2290	0.4668	86.6666
Centaurea melitensis	0.0020	0.0014	13.3333
Centaurea repens	0.0417	0.0651	66.6666
Centaurea solstitialis	0.0008	0.0003	6.6666
Cephalaria aristata	0.2788	0.2174	40
Cephalaria syriaca	0.0188	0.0330	26.6666
Chenopodium sp.	2.4855	0.3922	53.3333
Cirsium lanceolatum	0.0057	0.0094	40
Consalida arientalis	0.5168	0.1165	80
Convolvulus arvensis	3.9425	6.9465	100
Euclidium syriacum	0.0572	0.0524	66.6666
Galium aparine	3.224	1.8212	53.3333
Galium tricornutum	16.1689	8.1996	86.6666
Gypsophila sp.	9.6872	4.3198	93.3333
Hyoscomus niger	0.0973	0.0195	26.6666
Lathyrus aphaca	0.0273	0.0655	46.6666
Lathyrus sp.	0.0053	0.0314	6.6666
Lithospermum arvense	2.4348	1.3750	93.3333
Lolium multiflorum	0.5459	0.5535	80
Lolium temulentum	0.3463	0.5649	46.6666
Lycopsis arientalis	0.0036	0.0030	33.3333
Malva parviflora	0.0024	0.0035	13.3333
Marrubium peregrinum	0.1218	0.0312	60
Medicago hispida	0.0004	0.0027	6.6666
Melilotus officinalis	1.0742	0.3396	73.3333
Medicago rigidula	0.0012	0.0113	20
Medicago sativa	0.0004	0	6.6666
Neslia apiculata	0.3565	0.3041	80
Nicis benedictus	0.0004	0.0018	6.6666
Onobrichis sativa	0.0016	0.0034	26.6666
Onopordum acanthium	0.1431	0.1669	73.3333
Onopordum caucalis	0.0004	0.0004	6.6666
Ornithogalum narbonense	0.0020	0.0028	6.6666
Panicum italicum	1.3265	0.9461	53.3333
Patroselium sp.	0.0004	*0	6.6666
Phalaris minor	1.996	0.8158	86.6666
Poa bulbosa	0.2290	0.0823	66.6666
Polygonum aviculare	15.6675	6.7055	93.3333
Polygonum convolvulus	15.4316	9.7980	73.3333
Ranunculus arvensis	0.2040	0.4452	60
Rapistrum rugosum	0.3950	0.5838	80
Reseda lutea	1.1834	0.2179	86.6666
Rumex crispus	0.0392	0.0091	46.6666

Table 2 (Continue)
Number (%), weight (%) and frequency (%) of weed seeds obtained from the wheat flour mill plants in Konya Province

Salvia sclarea	0.0098	0.0056	33.3333
Secale cereale	1.0366	7.0405	93.3333
Setaria lutescens	1.6594	0.9391	53.3333
Silene caucalis	0.2564	0.0699	6.6666
Silene conoidea	2.9848	1.2447	86.6666
Sorghum halepense	0.0155	0.0105	26.6666
Sorghum sp.	0.0789	0.2787	13.3333
Thilapsi arvense	1.9371	0.3274	66.6666
Trifolium alexandrinum	0.0004	*0	6.6666
Vaccaria pyramidata	5.5476	2.7464	93.3333
Veronica triphyllos	0.1598	0.0320	26.6666
Vicia fabae	0.0151	0.3428	6.6666
Vicia pannonica	0.2024	1.5981	33.3333
Vicia peregrina	0.0032	0.0165	6.6666
Vicia sativa	0.1005	1.0539	26.6666
Vicia villosa	0.0245	0.1052	13.3333
TOTAL	99.9145	99.9722	

***** Quite close to 0

Intensity (Numerically)
0,0 6 % ≤ very intensive
0.02-0.06 % Intensive
0.01-0.02 % quite intensive
0.01% ≥ rarely encountered weed seeds

Frequency of Occurrence:
50 % ≤ very frequent
25-50 % frequent
10-25 % quite frequent
10 % ≥ rarely encountered weed seeds

In his study conducted in Van, Tepe (1998) determined that *S. cereale* took place on the top in terms of weight and numerical contamination. In our study, the mentioned species ranked among the top five and its frequency of occurrence was found as 93,3333 %. Also Karaca and Güncan (2009), determined that *S. cereale* seed was contaminated in wheat product with an average of 1.1536% numerically and 0.9522% by weight in Konya province.

Once again, in their study including the West of Anatolia, Güncan and Boyraz (2001) reported the species intensively contaminated in wheat as *S. cereale, Vicia* spp., *G. aparine* and *G. tricornutum.* In our study, *G. tricornutum* took place on the top numerically and ranked forth as weight. *S. cereale* also had a considerable percentage in terms of weight and frequency of occurrence.

Similarly, in their study conducted in Samsun, Mennan and Işık (2003) determined that *G. aparine* took place on the top in terms of intensity, Tursun et al. (2006) determined that *G. tricornutum* ranked fifth. Also Kaçan and Tursun (2019) were determined *G. aparine* as the most frequently contaminated weed seeds numerically in wheat crop.

Among the species determined as a result of the study, *A. aestivalis, A. flammea, A. githago, Chenopodium* sp., *C. syriaca, C. aristata, Cirsium lanceolatum, H. niger L. temulentum, L. multiflorum* and *V. pyramidata* have been reported to be toxic to humans and animals in different literature (Watt et al. 1962; Muzik (1970); Seçmen and Leblebici 1987; Picon et al. 1991; Suter 2002; Wagstaff 2008; Anonymous 2021).

4. Conclusion

It can reduce the contamination of weed seeds in wheat product to minimum by taking some measures such as; using pure seeds, passing through a selector, performing cultural and chemical control in the weedy fields. Today in Turkey, many weed seeds continue to contaminate in wheat product and maintain their development because of the reasons mentioned above. Definitely, in order to prevent this situation, it is our responsibility to raise the awareness of our farmers, to avoid incorrect agricultural practices being applied and to take necessary measures and to put them into practice.

Wheat is purchased from the Central Anatolia and outside region of the flour mill plants in Konya. As a result of the study, the detection of species with different ecological demands such as *Alopecurus myosuroides*, *A. sterilis*, *Bifora testculata*, *C. syriaca* and *Sorghum halepense* shows this result. Thus, different species of weeds enter the region. Weed seeds from flour mill plants are also fed to animals as forage. There is a risk of contamination of animal manures and thus agricultural lands due to climate change. In addition, weed species that are not in the region can be transported to the agricultural lands of the region with the use of animal manure. Therefore, weed seeds obtained from flour mill plants should not be fed to animals as forage. Or it should be aged for at least 6 months. Also, toxic species such as *Lolium* spp., *Chenopodium* sp., *Cephalaria* spp., *Adonis* spp., *A. githago, Hyoscyamus niger, V. pyramidata* present in weed seeds can harm animal health. The alkaloids contained in these toxic weeds can cause reactions and threaten human and animal health.

On the other hand, highly contaminating species are known as major weeds in farmlands. The species such as palmer amaranth (*Amaranthus palmeri*) are often reported to be herbicide-resistant and have been increasing in recent years worldwide (Gaines et al. 2010). Herbicide resistant weed seeds have been reported as contaminants in commercial grains (Michael et al. 2010; Shimono et al. 2010). The international grain trade is also a major pathway of introduction because various weed seeds contaminate grain commodities (Hulme 2009; Asai et al. 2007; Shimono and Konuma, 2008; Michael et al. 2010; Asav and Kadıoğlu 2014; Wilson et al. 2016).

With the increasing wheat import, weed seeds contaminated with wheat enter the country. The weed that adapts to a region can reach the economic thresholds level within a few years. In this way, a weed that was not previously found in the country may appear as a problem in the future.

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Research Article

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Evaluation of Plant Distribution Regularity in Sowing with Different Guidance Systems by GPS, GIS and Voronoi Polygons

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ABSTRACT

In this study, sowing was carried out with 3 different tractor guidance methods: operator-controled, GPS-controled and automatic-controled. The optimum nutrient areas required for each plant were evaluated using voronoi polygons. Voronoi polygons were used to obtain nutrient areas. Voronoi polygons were used to obtain living spaces. The plant coordinates taken with CORS-RTK GPS were loaded into the CBS program and the voronoi polygon for each plant was obtained. Comparison of nutrient areas was made with shape coefficients calculated using polygon area and perimeter values. Shape coefficient was 0.731 in operator-controlled application, 0.746 in GPS-controlled application and 0.715 in automatic-controled application. Compared to operator-controlled application, shape coefficients were found to be 2 % more in GPS-controlled application and 2 % less in automatic-controlled application. Although the shape coefficients are relatively less in the automatic-controlled system, it can be seen that better results can be obtained in terms of field success due to the advantages such as low workload on the operator, ease of application at night and improvements in time utilization coefficient. As a result of the statistical analysis, it has been found that there is no difference between the applications and can be used interchangeably. As a result, when the systems are compared with each other, it is seen that the automatic-controlled application is more successful.

1. Introduction

The main purpose of the sowing process is to place the seeds in a horizontal and vertical position in order to provide optimal conditions for germination, growth, inter-row processing and harvest (Páltik et al. 2005).

In addition to the use of good seeds in a quality sowing process, deciding on the right sowing method, choosing the right machine and correct application provides an increase in yield and reduces the cost by reducing unnecessary processes (Yazgı et al. 2012).

It has been observed that the development of agricultural products can be improved by regulating the spatial distribution of the plants (Andrade and Abbate 2005; Weiner et al. 2001).

In many studies, it is seen that the uniformity of sowing is determined by using only the inter-row distances. However, the main effective factor on yield and plant growth is the plant nutrient areas, and this should be examined in two dimensions (Karayel 2010; Karayel and Özmerzi 2010).

The quality of the horizontal and vertical distribution of seeds is affected by the distance between rows, sowing depth, soil condition, planter design, seed density and operator skill (Griepentrog 1998).

Better seed distribution mainly provides three main benefits: better yield and quality, better weed competition, more effective physical weed control and chemical application (Griepentrog and Blackmore 2007).

Computational geometry, which emerged as a research branch and can be tried relatively recently in other theoretical fields, finds many application areas in today's world. For example, the creation of digital terrain models, finding the shortest (not passing through obstacles) path between two points on a map, and calculating areas that represent points in a field are some of the most important problems that can be counted in this field (Karayel 2010).

While doing the delaunay triangulation, which is included in the computational geometry, "the segment

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of the line connecting each point with the point closest to it" forms a triangle side. (Figure 1). The triangles formed are the most likely equilateral triangles (equiangularity feature).

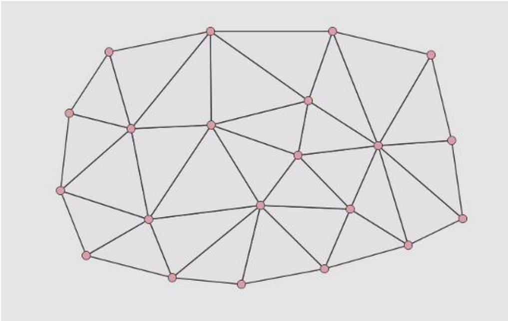

Figure 1
Delaunay triangulation

The voronoi polygon of a point separates any point from neighboring points closest to it. As seen in Figure 2, the edges of the polygon consist of the side center posts of the line segments connecting the point and the neighboring points (Yanalak 2001).

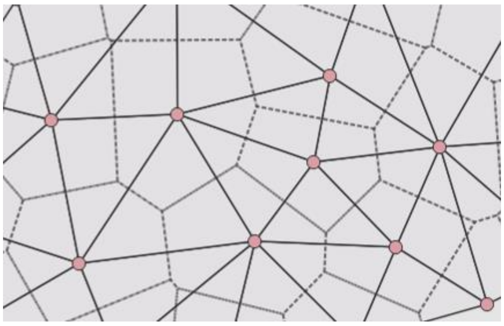

Figure 2
Veroni polygons

The aim of this study is to evaluate the plant distribution uniformity in terms of nutrient area by using GPS and GIS computational geometry by sowing maize with operator-controlled, GPS-controlled and domestic automatic-controlled guidance system.

2. Materials and Methods

This study was carried out in Selçuk University Faculty of Agriculture Sarıcalar Research and Application Farm in Konya province. In the study, 12 parcels of 100 m length and 2.8 m width were used for maize cultivation. In order to prepare a seed bed in the field, a vertical shaft rototiller with a toothed roller is used.

In the research, four rows and tractor mounted vacuum type pneumatic precision seed drill driven from the PTO was used. Seed discs with a hole diameter of 4.5 mm were used in the experiment. The seed spacing between the rows of the machine is 70 cm and the seed spacing along the row is set to 16 cm. The hoeing process was carried out with a interrow hoe machine and irrigation and fertilization was done with the drip irrigation system.

GPS-controlled sowing was done with the domestic guidance system of Agrisign company and Automatic-controlled sowing was done with the prototype control system integrated into the same system. The system consists of a laptop with GPS and automatic control software, CORS-RTK GPS antenna, rubber wedge servo motor, motor driver, wheel protractor, etc. additional equipment.

The system is mounted on the NEW HOLLAND brand TD 110 model tractor to be used in sowing In order to adapt the system to the tractor, the sheet material, which was drawn in the Solidworks program before and which has mounting holes on it to be fixed to the screw places on the tractor steering wheel, was cut on the laser bench and attached to the tractor. The steering wheel is moved by a servo motor that connects a rubber wedge to the shaft on the system, and this servo motor is placed in the plastic sleeve drawn in Solidworks program and then created with a 3D printer. The engine sleeve is attached to the sheet metal part mounted on the steering wheel, hinged and spring-loaded so that it can be separated from the steering wheel if desired. The general view of the system on the tractor is given in Figure 3.

Figure 3
General view of GPS and automatic control system

The steering system is set to move straight on the AB line before operation. The height of the GPS antenna, the hanging type of the equipment connected to the tractor, the working width and length of the connected equipment, the distance from the tractor and the distance from the GPS have been entered into the system beforehand. In GPS guided sowing, the servo motor is separated from the steering wheel and the operator uses the steering wheel by moving it to the right or left according to the directions on the program screen. In automatic mode, the servo motor is connected to the steering wheel and steering is made by the system automatically turning the steering wheel.

In the study, SATLAB brand SL 500 model GPS, handheld terminal and topcon brand carbon fiber pole working according to the CORS-RTK principle were used to determine the coordinates of the plants.

Satlab GNSS Office Software and Google Earth software were used to make the appropriate transformations of the location data obtained by GPS.

Viewing and processing the location data taken from plants, creating voronoi polygons, calculating their areas and perimeters were done with the QGIS GIS program.

A standard Asus laptop computer with Intel Core i5 2.4 GHz processor, 4 GB memory and 320 GB hard drive was used for running the programs and other data analysis. Statistical analyzer was done in Minitab program. Tape measure, digital caliper and charge balance were used in the measurements taken from the plants during the harvest.

Before sowing in the field, the seed bed was prepared with a vertical axis rotary tiller. The intrarow distance of the seeder, whose interrow distance is 70 cm, is set as 16 cm. The fertilizer norm of the seeder has been adjusted to be 40 kg DAP per decare.

On May 16, 2018, sowing was carried out with 4 replications according to the randomized blocks trial order with 3 different methods: operator-controlled, GPS-controlled and automatic-controlled.

Irrigation was done with drip irrigation and during cultivation, a total of 496 mm of water was given. During the cultivation, 1 time hoe and 1 time weed spraying was done. Top fertilizer was given by drip irrigation in the form of urea, in total 40 kg per decare after the hoe application. Mustang was used as a herbicide with 70 ml per decare. The maize in the plots reached harvest maturity on September 19, 2018, and harvest measurements were made on yield and quality characteristics on this date.

In order to determine the seed distribution uniformity of the plants, the nutrient area-based method consisting of the voronoi polygon of each plant was used. Theoretically, the ideal nutrient area of a plant is the circle. The shape coefficient was used to determine how close the created nutrient areas are to the ideal nutrient area, geometrically (Griepentrog 1998). The fact that the shape coefficient approaches 1 indicates that the nutrient area also approaches the circular shape at the same rate. The shape coefficient is the ratio of the circumference of the circle surrounding the ideal living area to the perimeter of the polygon calculated as the plant's nutrient area.

The coordinates of the plants in the 2 m section of each plot (4 rows) were measured with a high-accuracy CORS-RTK GPS device in order to determine the nutrient areas after the seedling emergence. The coordinates of the plants recorded by the GPS device were loaded into the QGIS GIS program after the appropriate transformations were made in Satlab GNSS Office and Google Earth Pro programs. By choosing the voronoi command in the QGIS GIS program, the voronoi polygons of each plant were calculated. Among these polygons, 20 polygons belonging to the middle rows for each parcel were selected to calculate their areas and perimeters. By entering the attribute table of the file containing the selected polygons, the polygon area and its perimeters are added to the attribute table with the option to create a new area option. After obtaining the area and perimeter of the polygons, the files of the polygons were saved in dbf format, which could be opened by the Excel program and the values in the attribute table could be seen from the save as menu. These files were opened in the Excel program and the ideal circle radius, circumference and shape coefficient values for each living area were calculated. The obtained shape coefficients were subjected to analysis of variance using Minitab program.

Plant height, number of cobs, height of cobs, stem diameter, leaf length, leaf width, plant weight, leaf weight, cob weight and stem weight were measured in 20 plants determined from each plot during the harvest.

3. Results and Discussion

Plant height, number of cobs, height of cobs, stem diameter, leaf length, leaf width, plant weight, leaf weight, cob weight and stem weight were measured during harvesting and the average of the repeated measurements was calculated. The results of these measurements are given in Table 1.

Table 1
Measurements taken from plants during harvest in field

Aplication	Plant height (cm)	Number of cob (piece)	Height of cob (cm)	Stem diameter (mm)	Leaf length (cm)	Leaf width (cm)	Plant weight (g)	Leaf weight (g)	Cob weight (g)	Stem weight (g)
Operator-controlled	258,03	1	89,18	24,99	93,05	9,88	833,73	136,48	270,53	426,73
GPS-Controlled	252,28	1	88,28	25,22	90,95	9,76	822,43	131,50	267,68	423,25
Automatic-Controlled	249,45	1	95,48	24,10	94,08	9,85	820,30	137,40	263,10	419,80

The images of the voronoi polygons obtained from all the plots where the sowings were made with the operator-controled, GPS-controled and automatic-controled guidance systems obtained in the QGIS GIS program are given in Figure 4, Figure 5 and Figure 6.

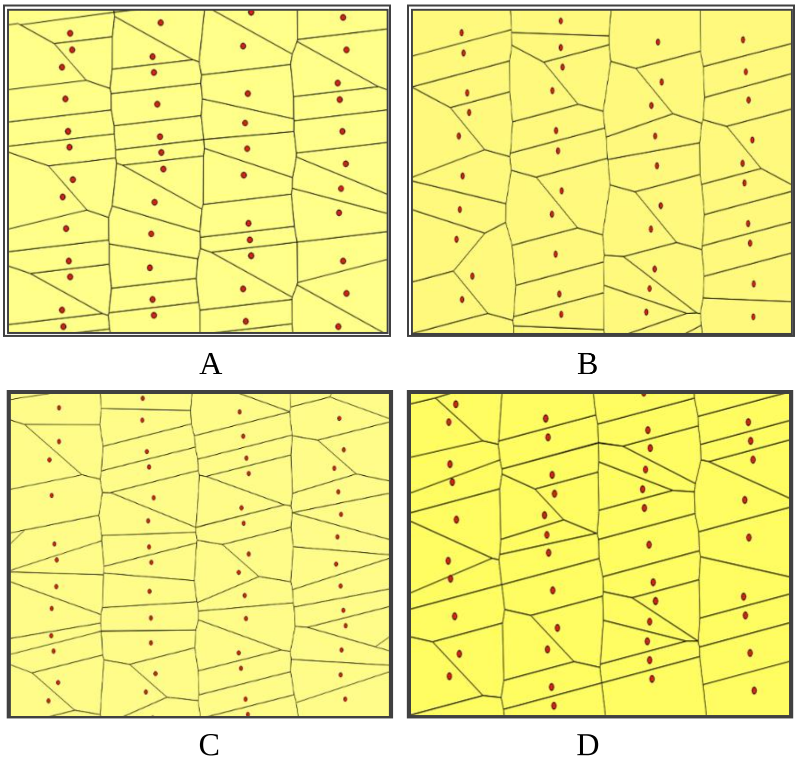

Figure 4
Veroni polygons of plant nutrient areas in operator-controlled application (A: 1st replication, B: 2nd replication, C: 3rd replication D: 4th replication)

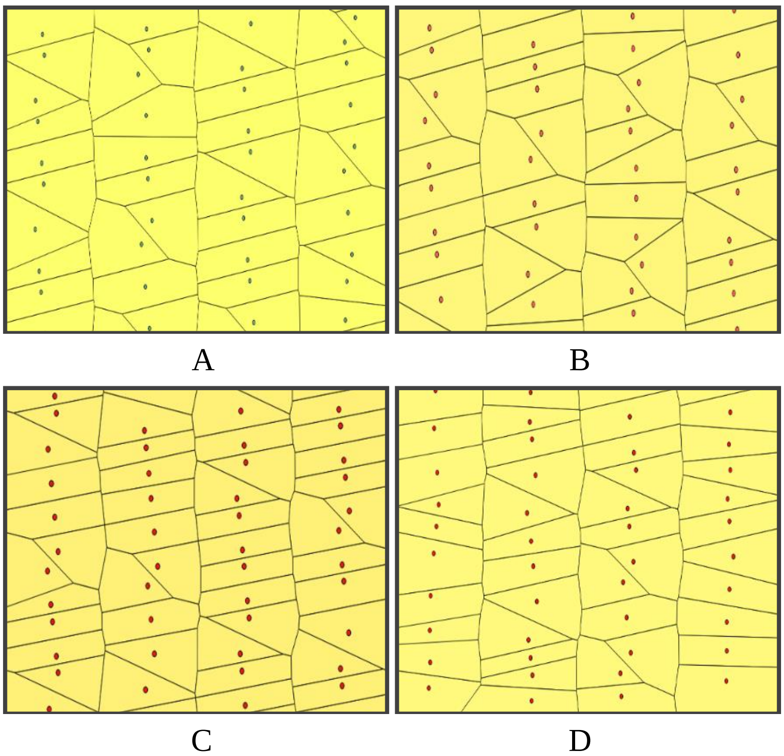

Figure 5
Veroni polygons of plant nutrient areas in GPS-controlled application (A: 1st replication, B: 2nd replication, C: 3rd replication D: 4th replication)

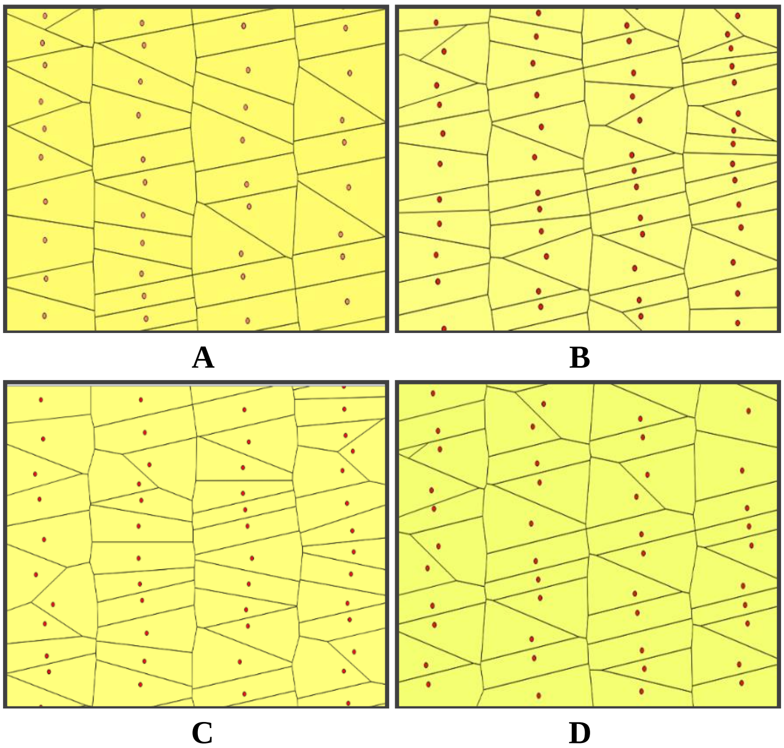

Figure 6
Veroni polygons of plant nutrient areas in automatic-controlled application (A: 1st replication, B: 2nd replication, C: 3rd replication D: 4th replication)

Shape coefficient values of application replications and averages are given in Table 2, and average shape coefficients are presented graphically in Figure 7.

Table 2
Shape coefficients of replications and averages

Method	Replication	Shape coefficient
Operator-controlled	1	0,727
	2	0,751
	3	0,730
	4	0,715
Average		0,731
GPS-controlled	1	0,761
	2	0,744
	3	0,739
	4	0,738
Average		0,746
Automatic-controlled	1	0,693
	2	0,723
	3	0,711
	4	0,731
Average		0,715

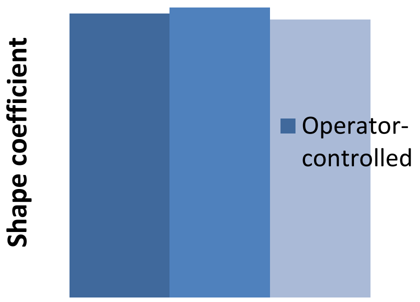

Figure 7
Average shape coefficients

When Table 2 and Figure 7 are examined, it is seen that the shape coefficient values vary between 0.693 and 0.761. The highest shape coefficient value was obtained in the 1st replication of the GPS-controlled application, and the lowest shape coefficient value was obtained in the 1st replication of the automatically controlled application. Considering the average values of the applications, the highest shape coefficient was obtained in the GPS-controlled application, and the lowest shape coefficient was obtained in the automatic controlled application. Compared to the operator-controlled application, the shape coefficient was found to be 2% higher in the GPS-controlled application and 2% less in the automatic-controlled application.

The obtained shape coefficients were subjected to logarithmic transformation before being subjected to analysis of variance. Normality test was performed according to the Shapiro-Wilk statistical method in order to understand whether the analysis of variance satisfies the assumption of normality. As a result of the test, P-Value values were greater than 0.05 for all applications and it was determined that the data showed a normal distribution. In addition, Bartlett and Levene tests were performed to understand whether the values showed a homogeneous distribution. As a result of the test, P-Value values of Bartlett and Levene tests for all applications were found to be greater than 0.05 and it was determined that the values showed a homogeneous distribution.

When the results of the statistical analysis of variance are examined, it is understood that the difference between the operator, GPS, and automatic controlled guidance applications is insignificant according to the statistical significance level of 5%.

When the literature is examined, there are very limited studies on the examination of seed distribution uniformity based on the determination of voronoi polygons and nutrient areas. When the existing studies (Karayel 2010; Karayel et al. 2012; Griepentrog 1998; NZI et al. 2017) are examined, it is seen that the obtained shape coefficient values have similar results with these studies.

Although the shape coefficient is found to be 2% less in the automatic controlled guidance application compared to the operator controlled guidance application, this difference is insignificant as seen in the statistical analysis. Therefore, automatic controlled guidance application is more advantageous due to its advantages such as less load on the operator and better utilization of time.

In this study, maize was sown in the field using the randomized blocks experimental scheme with operator-controlled, GPS-controlled and automatic-controlled guidance systems, and sowing evenness was evaluated in terms of shape coefficients calculated using nutrient areas. Theoretically, the ideal living space is the circle. The shape coefficient of the circle is 1, and the value of the shape coefficient of the living areas approaching 1 is an indicator of how close it is to the circle.

As a result of this study, in which operator, GPS and automatic controlled guidance were used, it was determined that the difference between all applications was statistically insignificant at the 5% significance level.

In operator-controlled guidance, there may be more fatigue and a decrease in efficiency because the operator will have more workload. GPS and automatically controlled guidance systems reduce the workload on the operator and provide a more effective working opportunity.

GPS and automatically controlled routing systems can also increase the time utilization coefficient by reducing the operator load.

The use of GPS and automatically controlled guidance systems can enable sensitive field applications that are difficult to be made at night, as well as at night.

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Research Article

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Determination of Vortex and Critical Submergence of Submersible Pumps

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ABSTRACT

In this study, submergence vortex and critical submergence of submersible pumps were investigated at different pump nominal diameters and water inlet cross-sections. Experiments were conducted with submersible pumps with three different outside diameters. For each pump, outlet pressure and inlet pressure measurements were performed at three different water inlet cross-sections, five different flow rates and different submergence.

Present findings revealed that for all three nominal diameters and cross-sections, critical submergence increased with increasing flow rates. The greatest critical submergence depth (1000 mm) was obtained from 3" pumps and the smallest critical submergence depth (10 mm) was obtained from 5" pump. Critical submergence increased with decreasing cross-sections. It was determined that there was an inverse relationship between the pump nominal diameter and the critical immersion depth. The critical dipping decreased with the increase of the pump nominal diameter. Critical submergence obtained at original cross-sections of submersible pumps were compared with the aid of a developed momentum equilibrium equation. The experiments were determined the submergence of vortex and vortex types. The vortex that occurred in all pump tests formed generally below the critical submergence.

1. Introduction

Since two different methods are used for power transmission to deep well pumps, there are two types of deep well pumps: vertical shaft deep well pumps and submersible deep well pumps. A typical submersible pump placed within the well, basic height terms, and well characteristics is presented in Figure 1.

Critical Submergence

The vertical distance between the pump water inlet and the dynamic water surface is defined as "submergence" (S). If the submergence is less than critical submergence (Sc), then a vortex is generated. As a result, the pump loses suction, and the efficiency decreases (Khanarmuei et al. 2018; Sarkardeh 2017a). Generally, critical submergence is associated with Sc / D (Eswaran et al. 2007; Khanarmuei et al. 2018; Ott 1995).

Most of the researchers have attempted to estimate critical submergence (Hite Jr and Mih 1994; Sarkardeh et al. 2010; Travis and Mays 2010; Yıldırım et al. 2012). Critical submergence in open canal flows and tanks were generally calculated with the aid of various empirical relationships (Ahmad et al. 2004; Khanarmuei et al. 2018; Sarkardeh 2017a; Yildirim and Kocabaş 1998; 2002; Yıldırım et al. 2000).

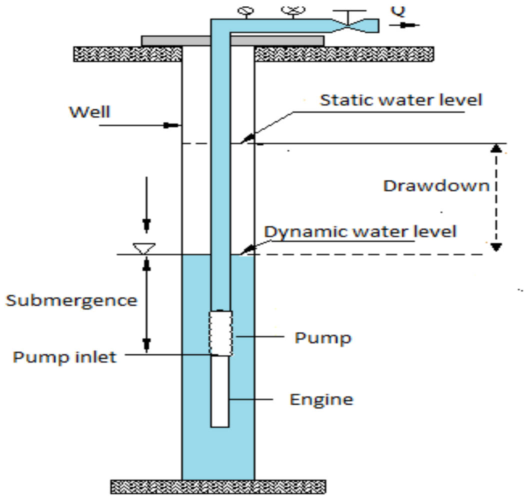

Figure 1
Deep well characteristic curve and basic height terms

There is no clear literature on the level of submergence during submersible pumps of well placing (Schulz 2013). Maximum 5 m submergences propose for vertical shaft deep well pumps.

It was stated in a study carried out in Konya province of Turkey that submergence of vertical shaft deep

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This article was derived from the author's Ph.D. Thesis

well pumps was quite above the ordinary values (5 m below the dynamic level). Submergence in deep well pumping irrigations was 20% deeper in 18%, 20-40% deeper in 47% and more than 40% deeper in 35% of the irrigations. (Çalışır and Konak 1998).

Submergence Vortex

Vortex is moving whirl generated by turning and pitting of water or air. The vortex frequently occurs in pump-intake due to unfavorable flow conditions or low submergence (Chen et al. 2012). The center of the vortex is appeared sharply after increasing the power of the vortex (Kirst et al. 2010). The potential of the vortex and air-inlet vortex at the pump-intake is changed by depending on the mean value of flow velocity and submergence. In the case of the formation of vortex depending on the depth of submergence, determination of the beginning of vortex is important for the observation of the various types of the vortex. The economic life and efficiency of the pump are affected by the interaction of the wings of the pump and air when the vortex occurs (Nagahara et al. 2001; Yildirim et al. 2011). If the air enters the pump after the formation of the vortex, there can exist cavitation (Okamura and Kamemoto 2005).

According to different energy levels, vortex formations are classified and shown in Figure 2. Sarkardeh et al. (2010) generally divided vortex into three classes. In their study, they defined a class C vortex as safe, class B vortex trash, and class A vortexes as dangerous. Knauss (2017) explained that vortices which occur in class 1 and 2 do not affect the operation of pumps. They reported that the vortices formed in classes 3,4,5 and 6 are dangerous.

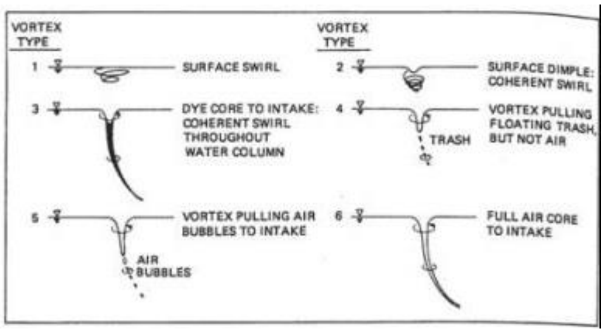


Figure 2
Vortex classification (Knauss, 2017)

Vortex in different shapes consists of a pump intake or suction line at the entrance with the decreasing water level (Azarpira, et al., 2014; Okamura et al. 2007). Okamura et al. (2007) reported that different vortex types occur at 230 mm water level in their study at a constant flow rate, while a continuous air inlet vortex occurs at 150 mm water level.

The pump manufacturers and installers usually do not take the risk of low submergence and thus they generally keep submergence as high as possible. As a result of this tons of processed material (column pipe) are unnecessarily submerged into waters, then investment costs increase, and operational costs increase because of redundant frictional losses. Such a case ultimately results in significant economic losses for both the facilities and the country. It is also possible to add installation labor and time spend for these operations to these losses.

In this study, critical submergence for submersible pumps to be placed in deep wells was tried to be determined and the basic factors affecting this critical depth were investigated.

The submersible pumps have determined the depth of formation of vortices and vortex type. For this purpose, submersible pumps were tested with the aid special testing setup at 3 different nominal diameters (D_1, D_2 and D_3), 3 different water intake cross-sections (CS_1, CS_2 and CS_3), 5 different flow rates (Q) and 5 different submergence (S). The parameters of outlet pressure (Po), inlet pressure (Pe), flow rate (Q), temperatures and relative humidity values were measured. To identify types of vortices were used cameras. With the resultant data, basic values for submergence of deep well pumps were put forth. Resultant critical submergence was compared with the developed momentum equilibrium equation.

2. Material and Method

2.1 Material

Experiments were conducted at Deep Well Test Unit of Prof. Dr. Şinasi YETKİN Practice Workshop in Agricultural Machinery and Technologies Engineering Department of Selcuk University Agricultural Faculty (Figure 3).

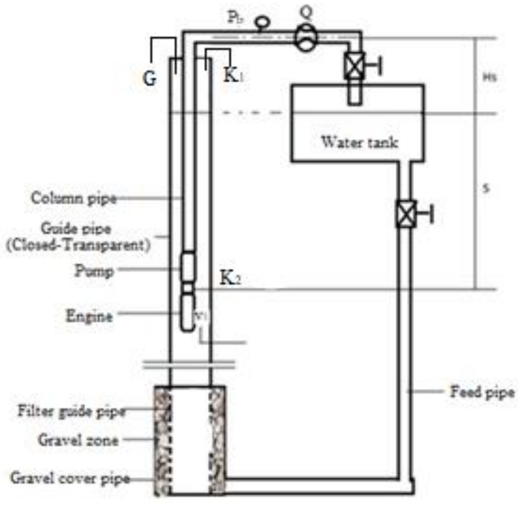


Figure 3
Deep Well Pump Test Tower and Installations

The test setup with a deep well has a total height of 10 m. From the bottom to top, the unit has 2 m oblong perforated filter guide pipe, 4 m closed guide pipe, 4 m transparent guide pipe. Perforated filter guide pipe is surrounded by 10 cm wide gravel layer with a bulk density of 1,54 kg m^{-3}, 7-15 mm geometric diameter. Technical specifications for the submersible deep well pumps used in the present experiments are provided in

Table 1. For pump actuation, 4 kW motor was used for D_1 pump, and 5.5 kW motors were used for D_2 and D_3 pumps. Technical specifications for measurement devices used in the present experiments are provided in Table 2.

Table 1
Technical specifications for submersible pumps

Technical specifications	D_1	D_2	D_3
Pump outside diameter (mm)	152.4	177.8	203.2
Pump material (TSE EN 1591)	Cast iron	Cast iron	Cast iron
Pump impeller material	Brass	Brass	Brass
Pump shaft material	Stainless steel	Stainless steel	Stainless steel
Inlet cross section (KA_2) (mm^2)	7200	9000	10800
Pump shaft diameter (mm)	25	25	30
Pump number of stages	2	1	1
Number of blades	5	7	6
Blade thickness (mm)	5	5	5
Impeller outlet diameter (mm)	94.5	140	150
Impeller outlet width (mm)	15	16	20

Inlet pressure (vacuum) was measured with the aid of a mercurial U-tube differential manometer installed at the bottom of the suction nozzle. The U-pipe differential manometer, 6 mm diameter, 2 m long transparent hose and 200 g mercury were used. Manometer installation is presented in Figure 5.

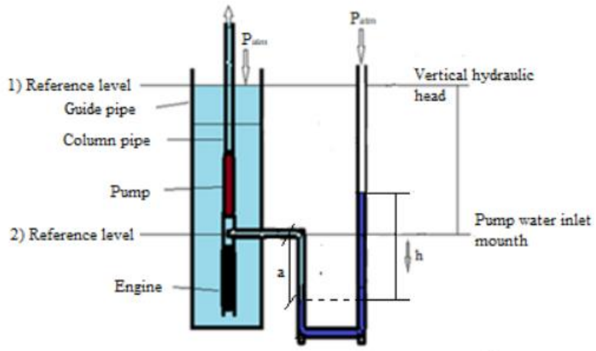
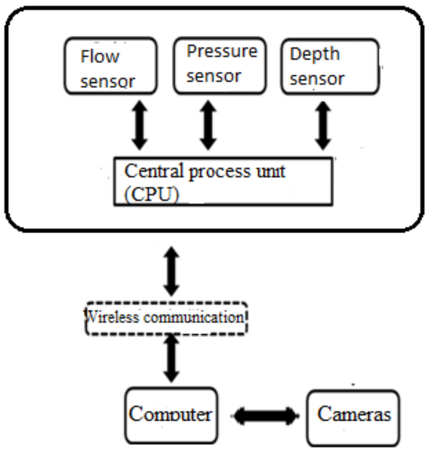


Figure 4
U-tube differential manometer



Figures 5
Block diagram of the automation system

Table 2
Technical specifications for measurement devices

Device	*Technical specifications*
Flow meter	S MAG 100 TİP, DN 80-100-125 flange connection electromagnetic flow meter, 220 V supplied digital indicator, instant flow, percent flow, total flow indicators. Adjustable 4-20 m/A plus and frequency output. Measurement error: 0.5%.
Electric Machine	-Suver, 380 V, 8.2 A, 50 Hz, 2869 1/min, 4,5 kW, shaft diameter :25 mm, water-cooler, 3x2.5mm^2 cable cross-section -Watermot, 380 V, 13.6 A, 50 Hz, 2780 1/min, 5,5 kW, shaft diameter :25 mm, water-cooler, 3x2.5mm^2 cable cross-section
Water level meter	Hydrotechnik brand, 010 type/1,5 V, 150 m scaled cable, voice and light indicator type.
Temperature sensors	Turck brand, 10-24 VDC, -50...100 0C, 4-20mA output.
Cameras	Radial axis camera; 1080p HD Sensor, 720p HD video Axial axis camera; 15.0 megapixels, Full HD video recording
Computer	Asus intel core i7.

2.2 Method

A software and automation system was developed to record the measured quantities. The block diagram of the system is presented in Figure 5. The sensor data are transferred to a computer through a wireless communication card. The information stored at the central processing unit was recorded by an operator at desired intervals and with proper names through a software interface. The recording process was arranged so as to get data in every second. The records was initiated after the pump regime and 50 data were received from a sensor.

Measurements at optimum operating speed were taken at 5-7 different dynamic water levels of 5 different flow rates. Initial values were recorded through operating the pump at a specified flow rate and then submergence depth was reduced. The flow rate altered with the descending water level was restored with the valve over the measurement pipe. In this way, measurements were recorded for 5 different submergence heights of each flow rate.

TS EN ISO 9906 standard was taken into consideration in the measurement of pump operating characteristics and relevant calculations (Anonim, 2014).

Experiments were conducted at 1880 mm pump submergence (constant hydraulic head). Drawdown was measured with a water level meter and submergence was calculated with the aid of Equation 1;

$$S = 1880 - \Delta \quad (1)$$

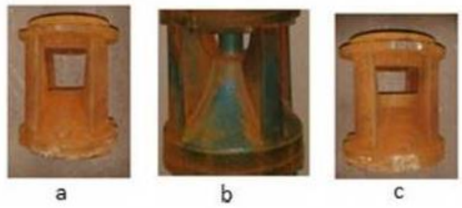
Where; S= Submergence depth (mm) and Δ = Depression (mm).

Additional to the original inlet cross sections of the pumps, an adapter was used to increase cross-section. A ring was installed on the adapter to get a smaller cross-section (Figure 6). Cross-sections are provided in Table 3.

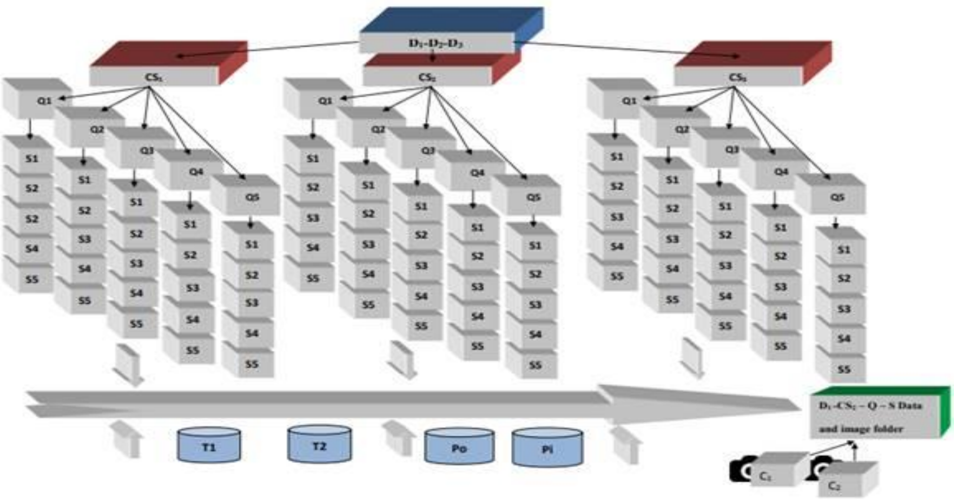
Different cross-sections were achieved by placing inlet adaptors without altering the cross-section shape. An adapter was supplied for each nominal diameter (a total of 6 adapters). One of these adapters was used as an original cross-section (CS_2) inlet adaptor. The other adaptors provided either 20% larger cross-section (CS_3) and 20% smaller cross-section (CS_1). The experimental design of the pumps is given in Figure 7.

Table 3
Pump inlet cross-sections (mm^2)

Pumps	CS_1 (20% smaller)	CS_2 (Original)	CS_3 (20% greater)
D_1	3800	4800	5800
D_2	7200	9000	10800
D_3	13500	16800	20000



Figures 6
Cross-section alteration ring placed at inlet adapters of the pump (a; %20 large adaptor, b; Orginal adaptor, c; %20 smaller adaptor)



Figures 7
Experimental design for submersible pumps

2.2 Determination of critical submergence

Critical submergence (Sc) was determined by taking the pressure measured at the pump inlet axis as explained below for a specific criterion.

Pump inlet pressure was determined with the aid of the U-pipe differential monometer installed at the pump inlet. As can be seen in Figure 5, the height h between the mercury level at the right arm of the U-pipe differential manometer and number 2 reference level was measured and recorded. Before the operation of the pump, the height h is equal to the vertical hydraulic head and submergence depth is at the maximum level. With the operation of the pump, the height h decreases with the increasing suction based on flow rate. Following the zero value of the h, vacuum pressure is created at the pump suction. Then, positive hydraulic heat at the guide pipe will not be able to compensate suction head at the pump inlet. The continuation of the decrease will continue the increase in the vacuum pressure. Further reduction of the drop may cause air to enter the pump. The h values were measured in mm in three replicates. With these h values, pressure at the pump inlet was calculated by using the following equation;

$$P_e = \frac{\rho_m g(h/1000) - \rho_m g(a/1000)}{1000} \text{ (kPa)} \quad (2)$$

Where; mercury density ρ_m =13600 kg m^{-3} and gravitational acceleration g= 9.81 m s^{-2}.

Then at constant flow rates, from the regression equations obtained from Pe equation as a function of submergence depth, the submergence (S) making the Pe value zero was determined, and they were taken as critical submergence (Sc).

Flow rates were measured from two different points of the experimental setup (Figure 3).

2.3 Theoretical minimum submergence with equilibrium equation of linear momentum

Conversion of mechanical energy into hydraulic energy in centrifugal pumps is explained by the Euler equation obtained by taking the momentum of angular momentum. Moving from this principle, an equation was obtained for theoretical minimum submergence (S_T) by writing the equilibrium equation of linear momentum as schematically presented in Figure 8 within the scope of preservation of momentum by taking the position of submersible pump in the well and water flow into consideration. In that equation, F_1 is the upward thrust of pumped water, F_2 is the downward water head at the pump suction inlet. At equilibrium, F_1=F_2, but F_2>F_1 is required for the theoretical operation of deep well pumps. According to this approach, the equation was written and reduced as follows. In the last equation, Ak (m^2) is an inner cross-section of the pump column pipe, Ah (m^2) is a cross-section of the ring between well guide pipe and pump column pipe and v (m s^{-1}) is the mean water flow rate in column pipe.

$Q=A_k*v$ and $F_1=\rho*Q*v$

then

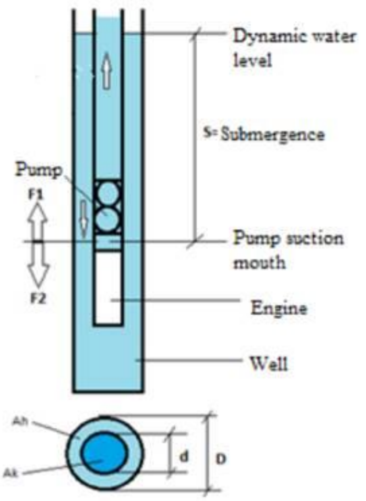
$F_1=\rho*A_k*v$

$F_2=\rho*g*A_h*S_h$

$F_2 > F_1$

$A_h*\rho*S_h*g \geq \rho*A_k*v$

$$Sh \geq (Ak/Ah)*(1/g)*v \qquad (3)$$



Figures 8
Schematic presentation of moment components effective in equilibrium position

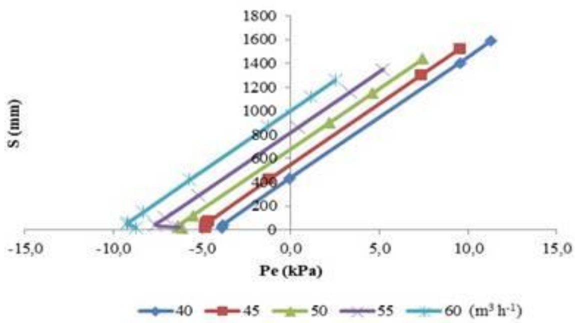
2.4 Determination of vortex type and submergence vortex

Two cameras for side-view and top-view were used to view the formation of the vortex. The place of the camera for the top-view was changed according to the water level and the camera angle. A side camera was attached to the pump inlet axis, outside the clear tube, to monitor the vortex formation (Figure 9). Vortex types are classified according to Figure 2 by examining the images taken from the cameras (Knauss, 2017; Papierski et al. 2012). The Submergence vortex (S_V) was observed at the moment of vortex formation and video recording was made. Vortex images were taken as images as a result of reviewing the recorded videos.

Figures 9
Submersible pump and connection of the camera

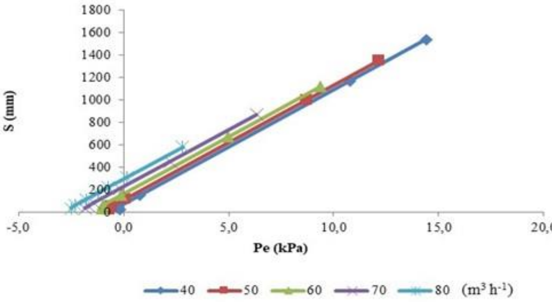
3. Results and Discussion

The Pe values of the pumps under constant flow rate are presented in Figures 10, 11 and 12 some combinations that will be examples as a function of submergence. Similar graphics were obtained in other combinations. Regression equations were derived from these functions and critical submergence where the Pe pres-sure value is zero was calculated and provided in Table4.



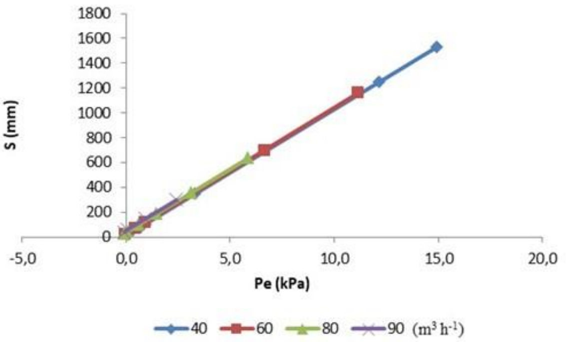
Figures 10
Changes in submergence and inlet pressures of D_1 pump at different flow rates and CS_1 inlet cross-sections

At constant flow rates and cross-sections, critical submergence decreased with increasing pump nominal diameters. Since the column pipe was fixed, well cross-section decreased with increasing pump nominal diameters. Such a case increased water inlet velocity to the pump, thus decreased critical submergence. Similar findings were also reported by Hanson (2000) and Christiansen (2005).



Figures 11
Changes in submergence and inlet pressures of D_2 pump at different flow rates and CS_2 inlet cross-sections

At constant pump nominal diameter, critical submergence increased with increasing flow rates. Most researchers have explained the critical submergence with the number of Froude. They reported that the increase in Froude number increased the critical submergence (Gordon 1970; Möller et al. 2015; Sarkardeh 2017; Sarkardeh et al. 2010). Since the increase in Froude is proportional to the increase in flow rate, in this study the increase in flow rate increased the critical submergence. Pumps reached critical levels earlier at high flow rates. At the same pump nominal diameter, increasing water inlet cross-sections reduced critical submergence. At increasing water inlet cross-sections, outlet pressures at the same flow rates increase and vacuum pressures decrease. Reduced vacuum pressures then caused pumps to reach critical submergence at lower submergence.



Figures 12
Changes in submergence and inlet pressures of D_3 pump at different flow rates and CS_3 inlet cross-sections

3.1 Relationship between critical submergence and theoretical submergence calculated

At the original cross-sections of the submersible pumps, the relationship between critical submergence (S_c) measured at different flow rates and the critical submergence calculated (S_T) with the developed equations are provided in Table 5.

According to pump inlet pressure measurements, it was observed that while calculated critical submergence (ST) of D_1 and D_2 pumps were quite above the determined critical submergence (Sc), Sc and S_T values of D_3 pump were close to each other. Therefore, it can be stated that the developed equation was appropriate for narrow well cross-sections. Besides, at constant flow rates, both Sc and S_T critical submergence generally decreased with increasing pump nominal diameters.

Table 4
Critical submergence depth (Sc) values (mm) of submersible pumps at different cross-section and flow rates

Q	D_1			D_2			D_3		
(m^3h^{-1})	CS_1	CS_2	CS_3	CS_1	CS_2	CS_3	CS_1	CS_2	CS_3
40	430	260	186	88	59	48	28	15	10
45	540	317	231	-	-	-	-	-	-
50	674	385	284	161	104	75	-	-	-
55	807	505	348	-	-	-	-	-	-
60	1000	593	411	245	153	112	62	36	23
70	-	-	-	350	223	153	-	-	-
80	-	-	-	464	290	198	114	68	40
90	-	-	-	-	-	-	146	82	51

3.2 Submergence vortex and vortex type

The video camera images recorded at two different axis (C_1 radial and C_2 axial) at different flow rate and submergence throughout the experiments have been investigated. The depths at which vortices begin to form and vortex types are given in Table 5. In the trials, the height at which vortexes began to form was determined as the depth of the submergence vortex (S_V). The vortex types have changed with the continued decrease in the height. Azarpira et al. (2014) stated that different vortex types were formed at different heights.

It has been seen that to occur air inlet continuous in the vortices formed at low submergence (20-40 mm). These vortices were determined entered type 4, 5 and 6 class. Okamura et al. (2007) emphasized the occurrence of continuous inlet of air at low submergence. The vortex type displayed at high submergence was determined as a cut type (type 1,2,3). Pump performances (Q-Pb) have fallen in vortex types which the air intake is constant.

Table 5
In the different flow rates critical submergence, theoretical submergence

	Q (m^3h^{-1})	Sc (mm)	S_T (mm)
D_1	40	260	43
	45	317	55
	50	385	67
	55	505	82
	60	593	97
D_2	40	59	26
	50	104	40
	60	153	58
	70	223	79
	80	290	102
D_3	40	15	19
	60	36	42
	80	68	75
	90	82	95

Different water movements have been observed in the pumps at constant flow rates and different pump nominal diameters. We can explain why different water movements occur, by changing the speed and vacuum values depending on the cross-sectional area of the well and by the different behaviour of water in the narrow area. This case can be explained by reason the fact that the D_3 pump with the formation of fluctuation high (20-60 mm) at the same flow rate and 50 mm in submergence (Figure 13b) while the D_1 pump occurs very little fluctuation high (5-10 mm) a flow rate of 40 m^3 h^{-1} and at 30 mm submergence (Figure 13a).

Some images of the types of vortices are given in Figure 14,15 and 16.

The vortex types at high flow rates and at low submergence have changed according to pumps nominal diameters. In the D_1 pump, vortex type 4 formation was observed at flow rates 60 m^3 h^{-1} and of submergence 50 mm (Figure 14). In the D_3 pump, the vortex formation was detected as type 1 at flow rates 90 m^3 h^{-1} and submergence 60 mm (Figure 15). We can explain why different types of vortex are seen that there is not enough space for the vortex to form due to the constriction of the well cross section in the pump with large nominal diameter.

a) b)

Figures 13
a) D_1CS_3 Q = 40 m^3h^{-1}; S = 30 mm b) D_3CS_3; Q = 40 m^3h^{-1}; S = 50 mm

C_1 C_2

Figures 14
D_1CS_3; Q = 60 m^3h^{-1}; S_V = 50 mm

C_1 C_2

Figures 15
D_3CS_2; Q = 90m^3h^{-1}; S_V = 60 mm

C_1 C_2

Figures 16
D_2CS_1; Q = 70 m^3h^{-1}; S_V = 60 mm

4. Conclusion

Maintenance of a water head over the fluid end of deep well pumps without any reductions in pump performance values is a significant issue for pumping economy and machine safety. Therefore, critical submergence of safe water head just before the generation of a vortex should accurately and simply be determined. In the present study, the vacuum pressure measurement method was proved to be reliably used to determine the critical submergence of submersible pumps.

Critical submergence increased with increasing flow rates at the same pump dimensions. Critical submergence of D_1CS_2 combination increased by 8-25% for each change in flow rate. Such increases varied between 24-38% in D_2CS_2 combination and between 20-62% in D_3CS_2 combination. It can be stated herein that greater flow rates and nominal diameters could be used for the same submergence.

Critical submergence inversely correlated with water inlet velocity into the pump, thus with pump nominal diameter. At the same flow rate, critical submergence of the pumps with low nominal diameter was greater than the values of the pumps with high nominal diameter.

At the same nominal diameters and flow rates, critical submergence of the pumps decreased with increasing water inlet cross-sections. Critical submergence measured at reduced inlet cross-sections decreased about 0.34 – 0.67 folds with increasing inlet cross-sections.

In practice, submergence usually kept quite high while placing the pumps into the wells. In present pumps, critical submergence were at quite low levels.

Performance losses were observed only at low submergence (20-150 mm). Therefore, it was thought that there was no need to place pumps into water meters deep and operate. Under constant well equipment and feeding conditions, it is ideal to take dynamic submergence as 2-3 m while installation of the pumps for a safe operation of the pumps.

The formed vortices that form in all pump experiments are usually below the critical submergence levels.

Provided that well equipment and feeding are constant, the relationship between well diameter and pump nominal diameter were considered as a significant parameter for vortex type and critical submergence.

5. Acknowledgements

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Determination of Salinity Tolerances during Germination Period of Some Lentil (*Lens Culinaris* Medic.) Cultivars

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ABSTRACT

In this study, in order to determine the resistance of registered lentil varieties to different salt concentrations during germination periods, this study was carried out in 2020 in University of Selçuk Faculty of Agriculture Department of Field Crops Laboratory in 4 replications according to the Randomized Plots Design. Çağıl, Çiftçi, Evirgen, Fırat-87, Kafkas, Özbek, Şakar, Şanlıbey and Tigris varieties were used as materials in the study. The effects of different salt concentrations (0 (control), 30 mM, 60 mM, 90 mM and 120 mM) on germination rate, germination speed, average germination time and sensitivity index were investigated. As a result of the study, it was determined that there were decreases in all the traits examined compared to the control application due to the increase in salt concentrations in all varieties. Especially in 90 and 120 mM NaCl applications, it was determined that the salt tolerance of the varieties decreased. Lentil varieties have been differently affected by salt applications, and the presence of genetic variation between varieties has helped us identify salt-resistant varieties. The varieties most sensitive to salinity were determined as Evirgen and Tigris. When all parameters are evaluated together, Özbek, Çağıl and Şanlıbey varieties have been determined as the best performing genotypes in terms of salt resistance.

1. Introduction

Soil salinity, which is among the factors that limit production because of improper use of natural resources or pollution due to various reasons, is increasing with each passing day (Flowers et al. 1997; Sözen and Karadavut 2017). The increase in the requirement for food in proportion to the increase in the world population with each day (Çakır 2018), and the scarcity of freshwater resources necessitate the search for alternative solutions (Acar et al. 2011). It was reported in previous studies that half of the agricultural areas in the world will not be used because of the salinity problem in the middle of the 21st century (Radi et al. 2013). The salinity problem in the soil affects plant production negatively in our country (Bağci et al. 2007; Atak 2014). It is extremely important to identify lentil varieties that can be productive in economic terms with high resistance to salinity in areas that have salinity problems and to recommend and grow these in these areas. The period when the cultivated plants are most sensitive to salinity is the first developmental period. Therefore, it is necessary to know the reactions plants show against salinity during the first developmental periods to determine the salt resistance of plants. This study was conducted to determine the salt resistance of lentil varieties registered in our country at different salt concentrations during germination periods.

2. Materials and Methods

The present study was conducted in University of Selçuk Faculty of Agriculture Department of Field Crops Laboratory in 2020 with Random Plots Trial Design at 4 replications to determine the resistance of lentil varieties registered in our country to different salt concentrations in germination periods. The study was conducted in dark conditions in a fully controlled germination cabin at a constant ambient temperature of 22±1.0°C; and 5 different NaCl doses (0 (control), 30, 60, 90, and 120 mM) were used in germination trials in the study. Specific germination pots that had a size of 20 x 10 cm, on which germination paper was placed, were used for germination. Solutions of NaCl that had concentrations of 0 (control), 30, 60, 90, and 120 mM were used for germination tests. The seeds of each variety were first kept at 1.5% sodium hypochlorite solution for 5 minutes and in distilled water for 5 minutes immediately after this to perform surface sterilization of the seeds of lentil varieties before germination. Also, 100 seeds with surface sterilization were

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placed in each germination pot used in the experiment, and distilled water or 20 ml salt solutions were added to each of them; and 0.5 g l-1 benomyl fungicide with active ingredient was added to the solutions to prevent fungal growth during germination. Çağıl, Çiftçi, Evirsen, Fırat-87, Kafkas, Özbek, Şakar, Şanlıbey and Tigris varieties were used as plant material in the study, and the effects of different salt concentrations on germination rate, germination speed, average germination time, and sensitivity index were investigated.

3. Results and Discussion

According to the results of the present study, the salt doses, variety and salt doses × variety interactions were found to be statistically significant at 1% in terms of germination rate, germination rate, average germination time, and sensitivity index; and the groupings and average values of the treatments are given in Table 1, Table 2, Table 3 and Table 4.

3.1. Germination Rate

When the general life cycle of plants is examined, it is reported that the most critical period in which plants are sensitive to salinity is the germination period (Aldemir and Ceyhan 2015; Uzun Kayıs and Ceyhan 2015).

When Figure 1 is examined, it is seen that the highest germination rate was observed in the control group at 88.14%, and the lowest germination rate was in 120 mM NaCl application with 72.06%. The germination rate of lentil varieties decreased as the salt dose increased from the control group towards the 120 mM NaCl application (Figure 1). The highest germination rate was detected in the Özbek variety (93.75%) as the average of the salt doses applied in the experiment, and the lowest germination rate was in the Evirgen variety (61.70%) (Figure 2). The significance of the Salt dose x Variety interaction in terms of germination rate shows that the germination rate of lentil varieties is affected differently by salt doses. It was reported in studies that tolerance to salt doses may vary in plant species, even in varieties in the same species (Aldemir and Ceyhan 2015; Gençtürk et al. 2015; Uzun Kayıs and Ceyhan 2015). In the light of these data, Özbek, Kafkas, and Şanlıbey varieties, which had high germination rates in high salt dose applications, were the varieties that should be emphasized.

Table 1
Germination rates of lentil varieties under salt stress (%)

Varieties	Salt Doses					Average
	Control	30 mM	60 mM	90 mM	120 mM	
Çağıl	75.25 mn	72.75 no	72.75 no	70.50 op	70.75 op	72.40 e
Çiftçi	93.75 cd	89.25 fg	86.50 ghi	80.00 kl	74.00 no	84.70 c
Evirgen	75.25 mn	67.25 pq	59.50 st	57.00 t	49.50 u	61.70 g
Fırat-87	83.25 h-k	71.25 nop	68.25 pq	64.25 qr	61.75 rs	69.75 f
Kafkas	93.75 cd	90.00 d-g	89.00 fg	86.25 g-j	83.00 ıjk	88.40 b
Özbek	98.00 ab	94.50 bc	94.00 bcd	92.75 c-f	89.50 efg	93.75 a
Şakar	96.50 abc	91.50 def	88.50 g	84.00 h-k	73.25 no	86.75 b
Şanlıbey	99.00 a	93.50 cde	87.25 gh	82.25 jkl	78.75 lm	88.15 b
Tigris	78.50 lm	80.25 kl	75.25 mn	70.00 op	68.00 pq	74.40 d
Average	88.14 a	83.36 b	80.11 c	76.33 d	72.06 e	80.00

CV%: 2,80; LSD (Salt Doses 1 %): 1.380; LSD (Variety 1 %): 1.851; LSD (Salt Doses x Variety 1 %): 4.139

[1]The difference between means shown with the same letter was insignificant.

3.2. Germination Speed

When Figure 3 is examined, it is seen that the highest germination speed was detected in the control group with 12.05 (days), and the lowest germination speed was in 120 mM NaCl application with 7.27 (days) as the average of the varieties. The germination speed of lentil varieties decreased as the salt concentration increased from the control group towards the 120 mM NaCl dose application (Figure 3). It was reported that the salt added to the germination medium increased the osmotic pressure in the water and prevented the uptake by seeds or decreased the germination speed with the toxic effect of ions, such as Na+ and Cl- (Goertz and Coons 1989; Esechie 1994; Kırtok et al. 1994; Özdemir and Engin 1994; Güvenç ve Kantar 1996; Essa 2002; Sadeghian ve Yavari 2004; Sözen and Karadavut 2019). The average of the salt doses applied in the experiment was at the highest germination speed in the Şakar variety (14.93 days), and the lowest germination speed was in the Evirgen variety (5.33 days) (Figure 4).

Şakar, Çağıl, and Şanlıbey varieties were the varieties that should be emphasized with their performance in terms of germination speed.

3.3. Average Germination Time

When Figure 5 is examined, it is seen that the average germination time of the varieties increased as the salt dose increased from the control group to 120 mM salt dose application. The highest mean germination time was obtained in 120 mM salt dose with 10.97 (days), and the lowest mean germination time was obtained in the control group with 8.10 (days) (Figure 5). Taiz and Zeiger (2002), reported that increased osmotic potential would occur depending on increased doses of NaCl in the salt solution, and may cause delayed germination time in the seeds. As the average of the salt doses applied in the experiment, the longest germination time was detected in the Kafkas variety (12.40 days), and the shortest germination time was detected in the Çağıl variety (6.38 days) (Figure 6). When the average germination times of the varieties were evaluated at different salt doses, the shortest germination time was detected in Çağıl, Şakar, and Şanlıbey varieties, respectively.

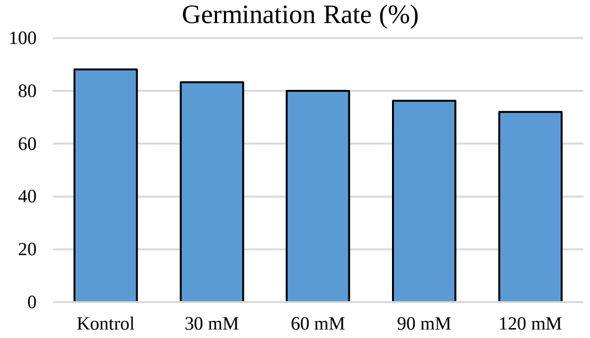

Figure 1
Germination rates of lentil varieties at different salt doses

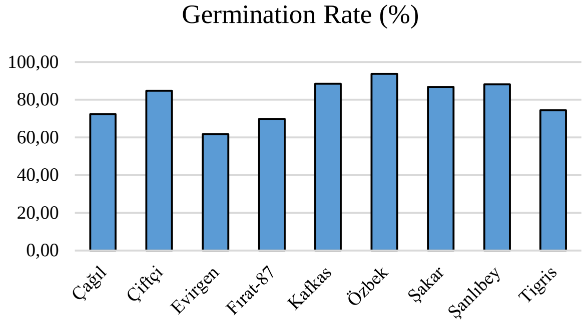

Figure 2
Average germination rates of lentil varieties at different salt doses

Table 2
Germination speeds of lentil varieties under salt stress (day)

Varieties	Salt Doses					Average
	Control	30 mM	60 mM	90 mM	120 mM	
Çağıl	12.47 e	12.66 e	11.86 ef	11.90 ef	11.26 fg	12.03 b
Çiftçi	15.04 c	12.11 ef	10.89 g	8.23 l-o	6.32 rs	10.52 d
Evirgen	7.69 op	6.09 st	4.69 uv	4.38 v	3.81 v	5.33 g
Fırat-87	12.07 ef	9.16 h-k	8.64 k-n	8.09 mno	7.36 opq	9.06 e
Kafkas	9.30 h-k	8.66 j-n	6.66 qrs	6.80 qrs	5.99 st	7.48 f
Özbek	9.54 hıj	9.96 h	9.88 h	8.78 i-m	8.99 i-l	9.43 e
Şakar	19.40 a	18.52 a	16.68 b	12.57 e	7.48 opq	14.93 a
Şanlıbey	13.83 d	12.16 e	10.93 g	9.65 hı	8.93 i-m	11.10 c
Tigris	9.15 h-k	7.83 nop	7.04 pqr	6.27 rs	5.31 tu	7.12 f
Average	12.05 a	10.79 b	9.70 c	8.52 d	7.27 e	9.67

CV%: 4,98; LSD (Salt Doses 1 %): 0.297; LSD (Variety 1 %): 0.398; LSD (Salt Doses x Variety 1%): 0.889

[1]The difference between means shown with the same letter was insignificant.

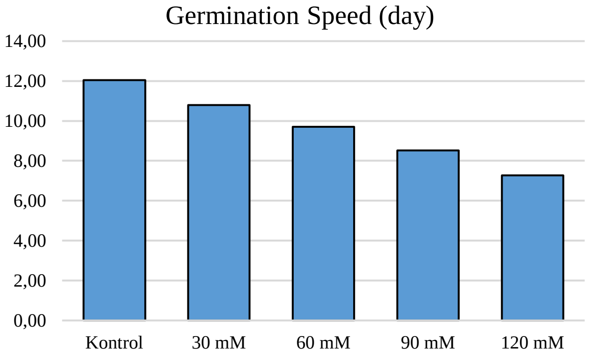

Figure 3
Germination speeds of lentil varieties at different salt doses

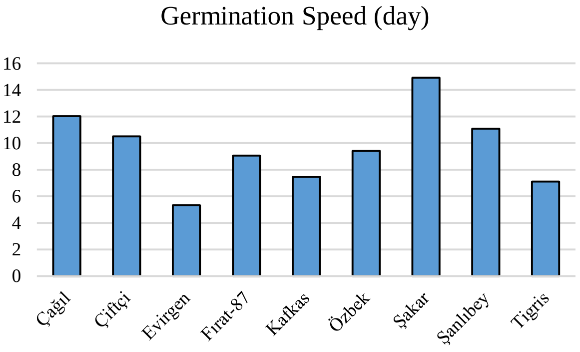

Figure 4
Average germination speeds of lentil varieties at different salt doses

3.4. Sensitivity Index

When Figure 7 is examined, it is seen that the sensitivity index increased as moved from 30 mM salt dose to 120 mM salt dose as the average of the varieties. Increased salt doses also increased the sensitivity index values of the varieties. The highest sensitivity index was detected as 1.40 in 120 mM salt dose, and the lowest sensitivity index was detected as 1.07 in 30 mM salt dose. As the average of the salt doses applied in the trial, the highest sensitivity index was detected in the Çiftçi variety (1.45), and the lowest sensitivity index was detected in Özbek variety (0.97) (Figure 8). In a study conducted by Tan and Akçay (2018), it was reported that as the average of the varieties, the increased salt level also increased the sensitivity index because of the prolonged germination period with the increase in the salt level. Similar results were also reported in previous studies (Aldemir and Ceyhan 2015; Aydın et al. 2015; Gençtürk et al. 2015; Uzun Kayıs and Ceyhan 2015). When the sensitivity values of the Increased salt doses also increased the sensitivity index values of the varieties were examined from 30 mM salt dose to 120 mM salt dose application, it was found that especially Özbek, Çağıl, and Şanlıbey increased salt doses also increased the sensitivity index values of the varieties were more tolerant to salinity than other increased salt doses also increased the sensitivity index values of the varieties.

Table 3
Average germination time of lentil varieties under salt stress (day)

Varieties	Salt Doses					Average
	Control	30 mM	60 mM	90 mM	120 mM	
Çağıl	6.19 stu	5.91 tuv	6.58 rst	6.28 stu	6.97 qrs	6.38 f
Çiftçi	6.59 rst	7.75 n-q	8.32 l-o	10.23 fgh	11.97 c	8.97 d
Evirgen	10.04 hij	11.42 cde	13.02 b	13.26 b	13.35 ab	12.22 a
Fırat-87	7.49 opq	8.70 klm	8.52 k-n	8.82 kl	9.27 jk	8.56 e
Kafkas	10.53 fgh	10.81 d-h	13.59 ab	12.93 b	14.13 q	12.40 a
Özbek	10.69 e-h	10.01 hij	10.00 hij	10.90 d-g	10.40 fgh	10.40 c
Şakar	5.14 v	5.13 v	5.50 uv	7.28 pqr	10.17 ghi	6.64 f
Şanlıbey	7.39 pqr	7.92 m-p	8.26 l-o	8.87 kl	9.32 ijk	8.35 e
Tigris	8.82 kl	10.53 fgh	11.04 def	11.63 cd	13.17 b	11.04 b
Average	8.10 e	8.68 d	9.43 c	10.02 b	10.97 a	9.44

CV %: 4,89; LSD (Salt Doses 1 %): 0.284; LSD (Variety 1 %): 0.381; LSD (Salt Doses x Variety 1 %): 0.853
[1]The difference between means shown with the same letter was insignificant.

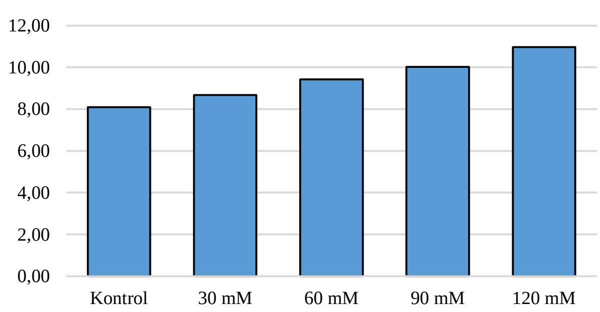

Figure 5
Average germination times of lentil varieties at different salt doses

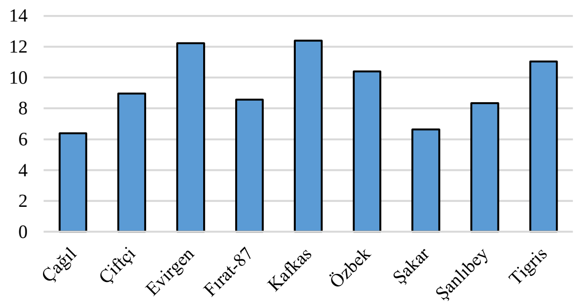

Figure 6
Averages of average germination times of lentil varieties at different salt doses

Table 4
Sensitivity index of lentil varieties under salt stress

Varieties	Salt Doses				Average
	30 mM	60 mM	90 mM	120 mM	
Çağıl	0.95 m	1.06 i-m	1.01 klm	1.13 h-k	1.04 f
Çiftçi	1.18 f-i	1.26 e-h	1.55 c	1.82 b	1.45 a
Evirgen	1.14 h-k	1.30 d-g	1.32 def	1.33 de	1.27 cd
Fırat-87	1.16 g-j	1.14 h-k	1.18 f-i	1.24 e-h	1.18 e
Kafkas	1.03 j-m	1.29 d-g	1.23 e-h	1.34 de	1.22 de
Özbek	0.94 m	0.94 m	1.03 j-m	0.98 lm	0.97 f
Şakar	1.00 klm	1.07 i-m	1.42 cd	1.98 a	1.37 b
Şanlıbey	1.07 i-m	1.12 h-l	1.20 e-i	1.26 e-h	1.16 e
Tigris	1.20 e-i	1.26 e-h	1.33 de	1.50 c	1.32 bc
Average	1.07 d	1.16 c	1.25 b	1.40 a	1.22

CV %: 6,35; LSD (Salt Doses % 1): 0.048; LSD (Ç Variety % 1): 0.072; LSD (Salt Doses x Variety % 1): 0.144
1The difference between means shown with the same letter was insignificant.

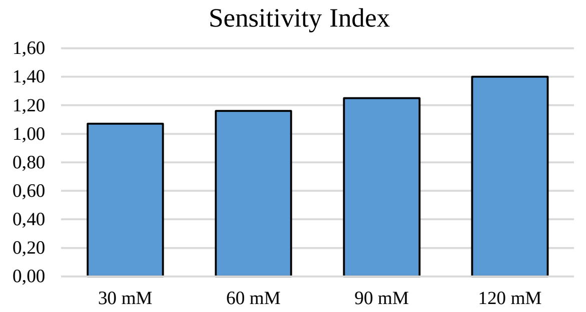

Figure 7
Sensitivity index of lentil varieties at different salt doses

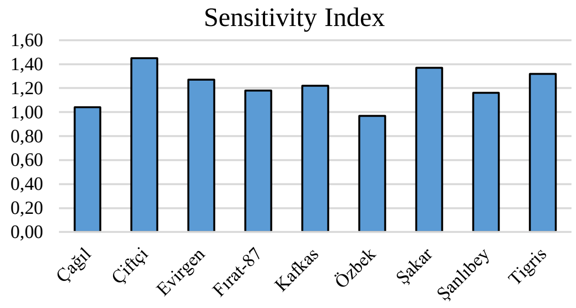

Figure 8
Average sensitivity index of lentil varieties at different salt doses

4. Conclusions

As a result of the study, significant differences were detected in the interaction of the variety, salt dose, and variety x salt dose in terms of germination rate, germination speed, average germination time, and salt sensitivity index values regarding the average of salt applications. The increased salt doses also increased the sensitivity index values of the varieties could not maintain their resistance at low salt doses at increasing salt levels. In terms of salt sensitivity, genetic differences at the germination phase were more evident especially at 90 and 120 mM NaCl levels.

As a result of the findings obtained in the study, it was concluded that salt application decreased the germination rates of the varieties, but on the other hand, it also caused a significant prolongation in average germination time because of slower germination of the seeds. As moved from 30 mM salt dose to 120 mM, the increase in salt dose also increased the sensitivity index; and lentil varieties were affected differently by salt treatments. Also, the genetic variations among varieties helped to identify salt-resistant varieties.

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Short Communication

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Comparison of Operational Parameters of Feed Mixing and Distribution Machines with Different Structures

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ABSTRACT

Recent supports provided to livestock operations also supported the development of mechanization levels used in these operations. Technological progress especially in herd management systems, automatic milking, cleaning and hygiene systems led to significant progress also in feeding mechanization. Especially during the last 10 years, significant numbers were achieved in manufacture of feed mixing and distribution machines with a great role in animal feeding in livestock operations. In Turkey, various types of feed mixers with different capacities and constructions are manufactured. These machines generally have single or double augers positioned horizontally or vertically. Such differences in machine constructions are generally resulted from manufacture easiness, cost items and feed characteristics. In present study, considering the average size of livestock operations of Turkey, three feed mixing and distribution machines with different constructions and 6 m^3 vagon capacity were compared in terms of operational conditions and assessments were made accordingly.

1. Introduction

Ever-increasing populations, cost of energy required and used to sustain daily activities and continuously depleted resources obligate efficiency and cost-reduction in agricultural activities as it was in the other aspects of life. Different from plant production activities, animal production could be implemented independently from the seasons. Mechanization applications with a great progress in every aspects of agriculture also achieved significant progress in livestock activities. In livestock operations, different mechanization tools and equipment are used for special purposes. Among them, there are feed mixers and distributors able to chope and mix the feed ingredients at desired quality and properly distribute mixed feed into feeders. These machines, playing a great role in animal nutrition in terms of meat and milk yield, are manufactured at different constructions and capacities.

According to TUIK (Turkish Statistics Institute) data, number of feeds mixing and distribution machines increased significantly during the last 10 years and by the year 2019, the number reached to 37 851 machines. Potential use of professional agricultural mechanization tools and equipment, especially feed mixing and distribution machines, in livestock operations play an important role in performance and efficiency of the operations, especially for meat and milk yields.

In feed mixing and distribution machine tests, the time spend to transfer feed admixtures into the machine, mixing duration, pouring duration, mixture homogeneity, power and fuel consumption are evaluated (Anonymous, 1999).

Kop (2002) indicated the objective in fish feed production as homogeneous distribution of nutrients and performance of mixing in a cost, labor, energy and time-efficient fashion. The assessments were made based on CV values and the values <10% were indicated as perfect, the value of between 10-15% were indicated as well (mixing time should be increased by 25-30%), the values of between 15-20% were indicated as poor (mixing time should be increased by 50%) and the values >20% were indicated as highly poor.

Yalçın et al. (2007) compared two feed mixing and distribution machines (one was imported, one with 8 m^3 and the other one with 4 m^3 capacity) in terms of the time spend in loading, mixing and pouring processes. Size analyses were conducted for feed materials before and after mixing and homogeneity of mixture was determined with the use of 2% trace elements. Researchers indicated that experimental results varied based on structural characteristics of the machines,

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operational conditions and different behaviors of operators and further research was recommended for better assessment of distribution of resultant values.

Çakmak (2008) indicated feeding as the most time-consuming process after milking in dairy operations and pointed out that success could be achieved in feeding with the use of proper machines. It was also indicated that to improve milk yields, proper rations including sufficient quantities of roughage, green fodder, silage feed and concentrate feed, thus feed mixing and distribution machines should be designed and developed accordingly.

Şeflek (2018) conducted a study for manufacture and operation of 1.5 m^3 capacity self-propelled feed mixing and distribution machine and designed a prototype and manufactured the machine. Machine performance tests were conducted with the use of five different feed materials (maize silage, barley straw, concentrate feed, wheat bran and dry alfalfa) and a trace element (kernel corn). The machine was operated with 326.5 kg ration and following the chopping and mixing processes, average chopping length was identified as 8.97 mm and trace element variation coefficient was identified as 12.05%.

Sağlam (2019) indicated that differences in feed mixing machines are generally resulted from differences in vagon and auger structures. Feed mixers are classified based on auger position as vertical, horizontal and inclined-axis. It was also pointed out that a homogeneous mixture of feed ingredients should be supplied to animals to improve animal performance and yield levels.

In present study, feed mixing and distribution machines with 3 different constructions were compared in terms of operation performance, power and fuel consumptions.

2. Materials and Methods

Present experiments were conducted in Livestock Operation of Selçuk University Agricultural Faculty Animal Science Department. New Holland TD110 D model agriculture tractor (110 HP) was used as the power source. Feed mixing and distribution machines with 3 different constructions (so called as type A, B and C) and 6 m^3 vagon capacity were used in present experiments. Type A mixer has one horizontal auger at the bottom and two horizontal augers at the top; Type B has one vertical auger and Type C has two horizontal augers at the bottom. Augers were all so designed as to provide material circulation within the vagon while mixing. The blades on augers facilitate chopping of the feed materials. Specifications and powertrain of the machines are presented in Figure 1.

Four different feed materials (hay, dry alfalfa, bran and concentrate feed) and a trace element (corn) were used in present experiments. Relevant preparations were made before the machine tests, materials were weight and made ready for time and fuel measurements and relevant measurements were made under the same operational conditions. Power measurements were made with a pto-driven torque meter (Datum brand 2000 Nm torque measurement capacity) and fuel measurements were made with the use of fuel meter device (Aqua metro CONTOIL DFM-BC) integrated into tractor fuel system.

Feed materials to be loaded into the machines were weighed and classified before the experiments. Each machine was operated with similar feeding conditions and relevant measurements were made throughout the experiments with the use of a chronometer. In present measurements, time spend to load the materials into the machine, mixture time following the loading of all materials and total pouring time following the mixture were measured. Total operation time was limited for 30 minutes for each machine. The time, power and torque measurements made throughout the experiments were used to assess operational performance of the machines.

3. Results and Discussion

Measured values throughout the experiments are provided in Table 1. Differences in measured values were mostly resulted from differences in machine design. Considering the time spend in loading the feed materials into the mixer vagon, the lowest value (396 s) was observed in Type A and it was respectively followed by Type C (459 s) and Type B (555 s) mixer. The reason for high loading time of Type B is greater vagon height and two-stage control of unloading of loading bucket (rising the bucket to vagon top and unloading position). Lower vagon heights and single-stage operation of loading bucket facilitated loading process in Type A and C machines.

In terms of instantaneous torque and fuel consumptions of the machines, generally low values were seen during concentrate feed loading process. Instantaneous torque and fuel consumptions started to increase with the loading of roughage into the machines. The lowest average torque need (118.70 Nm) and fuel consumption (3.75 l h^{-1}) were observed in Type C machine. The greatest torque and fuel consumption values were seen in Type B because of greater auger rpm of this type as compared to the others and quite different construction characteristics from the others. In terms of total mixture duration, lower feeding times increased the mixture durations.

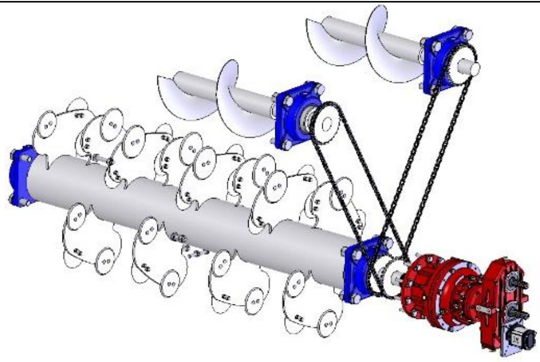
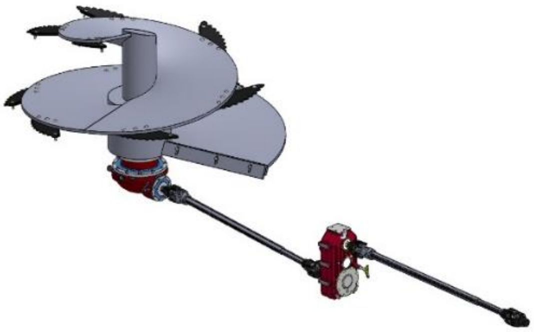
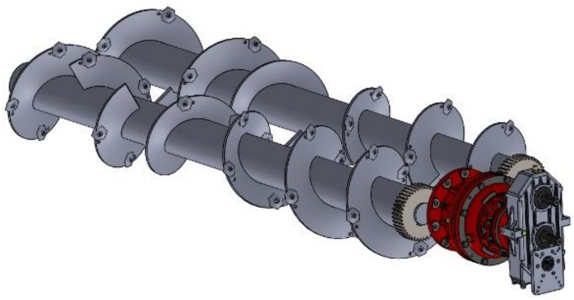
Type	**Powertrain**
6 m^3 vagon capacity one horizontal auger at the bottom and two horizontal augers at the top (**Type A**)	
6 m^3 vagon capacity one vertical auger (**Type B**)	
6 m^3 vagon capacity two horizontal augers at the bottom (**Type C**)	

Figure 1
Specifications and powertrains of experimented feed mixers

Table 1
Experimental Results

Machine type	Concentrate feed loading			Roughage loading			Feed mixing			General outcomes			
	Time (s)	Instantaneous fuel consumption (l h^{-1})	Instantaneous torque (nm)	Time (s)	Instantaneous fuel consumption (l h^{-1})	Instantaneous torque (nm)	Time (s)	Instantaneous fuel consumption (l h^{-1})	Instantaneous torque (nm)	Average fuel consumption (l h^{-1})	Average torque (nm)	Total operation time (s)	Total pouring time (s)
Type A	213	3.25	94.55	183	4.12	153.08	414	3.97	141.04	3.78	129.55	810	145
Type B	348	3.13	87.62	207	4.81	179.72	396	5.30	209.36	4.41	158.90	951	75
Type C	228	2.71	48.38	231	4.17	137.40	381	4.37	170.34	3.75	118.70	840	110

4. Conclusion

Improved efficiency in agricultural mechanization applications entails input cost reductions. In this sense, torque requirements and fuel consumptions of three different feed mixer machines with the same capacity to mix and chop the feed ingredients were compared in this study. In terms of operational conditions, purchasing costs, amortizations and economic lives of the machines should also be taken into consideration while selecting among available machines. Improvements could be achieved in torque requirement and fuel consumption of the machines with research and development activities on machine design and constructions.

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