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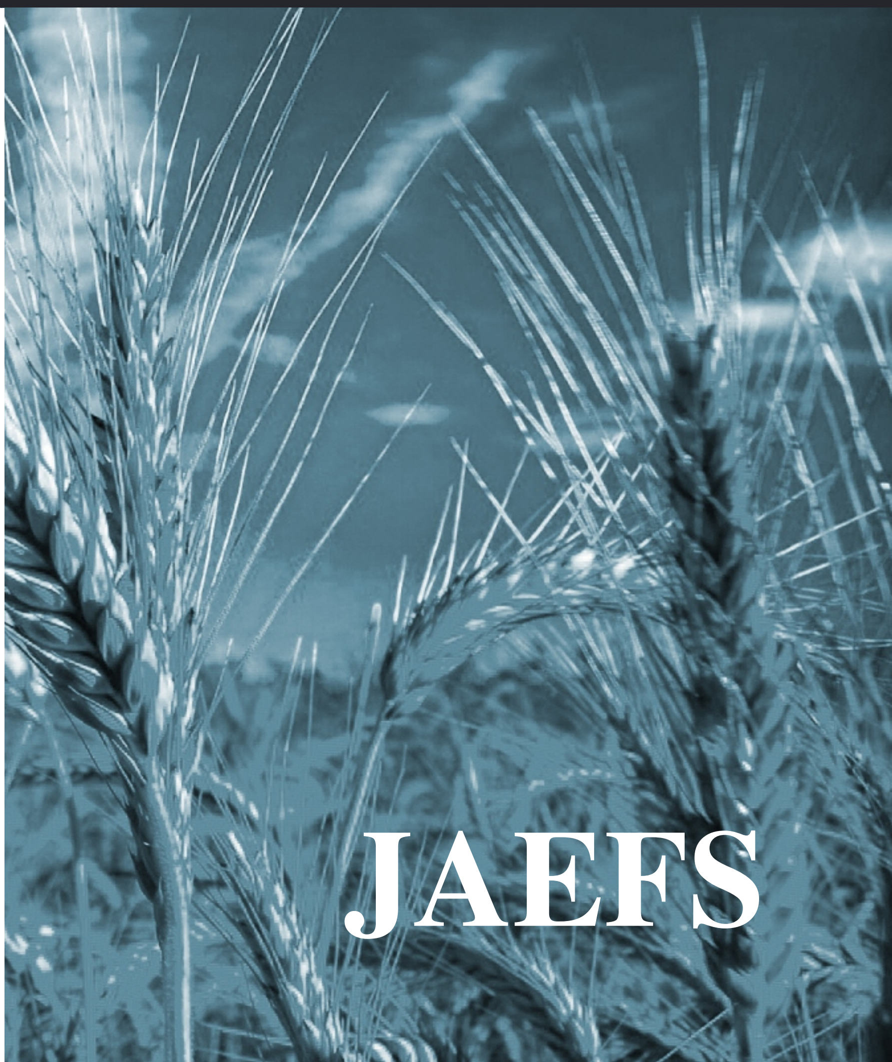

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The evaluation of the yield and yield components of seven soybean (*Glycine Max.* L. *Merill.*) genotypes grown as a second crop under Sirnak condition

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Abstract

In this study investigated the seed yield, oil rate, protein rate, yield and yield components of seven different soybean varieties that were from different maturation groups and grown under conditions. The trial was carried out in a farm land in Kurtuluş Village of İdil Town, Şırnak, Turkey in 2018 crop season. The study was designed in accordance with the randomized block design and carried out in three replications. In the study, important properties such as seed yield, oil content, crude oil content and yield components were investigated. The results showed that the seed yield values of the investigated soybean genotypes ranged from 2617.0 kg ha^{-1} to 3762.5 kg ha^{-1} and the highest seed yield values were obtained with the Asya (3762.5 kg ha^{-1}), Adasoy (3330.2 kg ha^{-1}) and Türksoy (3317.4 kg ha^{-1}) varieties. The oil contents of the soybean genotypes varied between 19.90% and 21.23% and protein contents varied between 32.59% and 35.44%. The Adasoy (35.44%) variety had the highest protein content. The results revealed that the genotypes can be successfully grown under second crop conditions in terms of growing time and yield.

Keywords: Soybean, Yield, Protein rate, Oil rate

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Introduction

Soybean seeds contain 18 – 26% oil and 40% protein. The glycine in the seed is highly important in animal nutrition. Moreover, its richness in oleic and linoleic oil ty acids and low linolenic oil content add to the quality of soybean oil. As a plant containing various vitamins and valuable amino acids and supplying nitrogen to soils in the form of organic substances, soybean is grown in Turkey both as a main crop and a second crop. In Turkey, soybean is predominantly used in the feed sector. Soybean cake contains high amounts of protein and thus, large amounts of soybean are used as a good source of animal feed especially in the feed rations for poultry. The top four materials preferred in the compound feed industry include full oil soybean, soybean cake, sunflower cake and cottonseed cake, while soybean ranks the first (Oner, 2006).

Among the oil plants worldwide, soybean ranks first in terms of cultivation area and production. According to the data of Food and Agriculture Organization (FAO), the global cultivation area, production and yield of soybean in 2017 were 123.5 million hectares, 352.6 million tons and 285.4 kg da^{-1},respectively. In Turkey, it ranks fourth in the cultivation area of oil plants and second in production. In 2017, the soybean cultivation area, production and yield in Turkey were 31.6 thousand hectares, 140 thousand tons and 4420 kg ha^{-1}, respectively (FAO 2017). Of the total soy cultivation in Turkey, approximately 91% took place in the Mediterranean Region including cities such as Adana, Osmaniye, Hatay, Mersin and Kahramanmaraş, 8% took place in the Black Sea Region, around Ordu and Samsun, 1% took place in the Aegean Region (Anonymous, 2017). Today, soy is produced as a main crop in Thrace, Marmara, Black Sea and Mediterranean and as the second crop in Southeastern Anatolia and the irrigable farm lands of the Mediterranean Region.

Soybean has a high yield potential and the selection of the appropriate genotypes and quality of the seeds are the leading factors affecting the yield and yield components. The appropriate genotypes should be selected by considering the sowing times and seeds with a high germination power should be preferred. Otherwise, maximum yield cannot be achieved regardless of the application methods.

High-quality and high-yield genotypes that are suitable for the ecological conditions of Turkey are needed. Wheat is sown as the main crop and soybean is sown as the second crop. The determination of the high-quality and high-yield soybean genotypes that are suitable for the second crop agriculture in Şırnak will be beneficial both to the farmers and to Turkey.

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Material and Methods

The trial was carried out a farm land in Kurtuluş Village of İdil Town, Şırnak, Turkey in 2018 crop season. The experiment was designed in accordance with the randomized block design and carried out in three repetitions. Seven soybean genotypes from different maturation groups (Lider, Bravo, Asya, ANP 2018, Nazlıcan, Türksoy, Adasoy) were used as the study material. The genotypes used in the trial were obtained from Eastern Mediterranean Agricultural Research Institutes and seed companies.

The climatic conditions of the study area: The location is under the subtropical climatic conditions and affected by the "Arabian-Peninsula Climate". The region is hot and dry in summer and receives little rain in winter. Precipitation decreases in winter and autumn. The mean monthly temperature during the trial ranged from 28.3°C to 32.5°C. In the experimental year, the maximum temperature in Şırnak reached 39.0°C in August. According to the data on precipitation, rainfall during the trial varied between 0.4 mm and 28. mm. Due to the insufficient precipitation, the water requirement was met by irrigation. The soils on which the trial was carried out were clay-loamy and had a pH of 8.12. The salt content of the soils was 0.03% and salinity problem was not observed in the soils. The lime content was 10.8% and, hence, the soils were mildly calcareous. Organic substance content was 0.71% and the soils contained low levels of phosphorus (2.75kg da^{-1}). The soils were highly rich in potassium (K).

The experiment was established in accordance with the randomized block design and carried out in three replications. The seed bed was prepared for sowing by the processing of the trial areas with a cultivator after the wheat harvest. Before sowing, 20 kg 18-46 (DAP) (36 kg ha^{-1}) N and 92 kg ha^{-1} P) per decare was applied to the area and, then, before the first irrigation, 20 kg da^{-1} 26% ammonium nitrate (52 kg ha^{-1} nitrogen) was applied as the fertilizer. In the trial, parcel size was 5.0 m x 2.8 m = 14 m^2 and each parcel contained 4 rows. Row spacing was adjusted to 70 cm x 5 cm. Sowing was carried out manually on June 26. The necessary maintenance work was carried out during the growing period using the appropriate methodology in a timely manner. Row irrigation was carried out for four-five times, depending on the water requirement of the plant. The harvest of the investigated genotypes took place in the second week of October, depending on the maturation status of the genotypes.

The plant height (cm), first pod height (cm), node number (nodes $plant^{-1}$), pod number (pods $plant^{-1}$), number of seeds (seeds $plant^{-1}$), 100-seed weight (g), oil content (%), protein content (%) and seed yield (kg ha^{-1}) of the genotypes were investigated.

The variance analysis of the data was performed using JMP 5 (SAS Institute Inc.) statistical software in accordance with the randomized block experimental design. The differences between the mean values of the factors that had a significant effect on the investigated properties were determined using the Tukey (0.05) test.

Results and Discussion

Table 1 shows the combined variance analysis results for the properties of different soy genotypes. The effects of plant height, first pod height, number of pods, number of seeds per plant, seed yield, 100-seed weight, protein content and oil content were statistically significant at the P<0.05, while there were insignificant differences between the genotypes in terms of node number.

Table 1. The results of analysis of variance for soybean.

Source of variance	DF	Plant height	The first pod height	Node number per $plant^{-1}$	Pod numbers per $plant^{-1}$	Seed numbers per $plant^{-1}$	Seed yield	100 Seed-weight	Protein rate	Oil rate
Genotype	6	*	*	ns	*	*	*	*	*	*
CV		9.09	7.91	12.22	12.98	9.97	10.98	10.96	2.84	3.67

ns: not significant, *significant at P < 0.05

Table 2. Mean performance and LSD ranks of the soybean and examined features.

Genoteypes	Plant height (cm)	The first pod height (cm)	Node number per $plant^{-1}$	Pod numbers per $plant^{-1}$	Seed numbers per $plant^{-1}$	Seed yield (kg ha^{-1})	100 Seed-weight	Protein rate (%)	Oil rate (%)
Lider	36.82 b	9.40 b	11.60	33.93 bc	80.40 de	2617.0 c	9.71 cd	33.16 bc	21.23
Bravo	45.01 a	11.00 a	9.53	32.60 c	68.54 e	2325.7 d	8.63 d	34.73 ab	21.21
Asya	44.15 a	10.60 ab	9.73	44.13 b	120.73 b	3762.5 a	13.96 a	33.57 bc	20.98
ANP 2018	42.65 ab	7.40 c	7.66	38.43 bc	101.66 c	2955.9 bc	10.96 bc	34.02 abc	20.13
Nazlıcan	44.16 a	9.66 ab	10.40	44.46 b	96.40 cd	3001.1 bc	11.13 bc	32.59 c	20.07
Türksoy	49.09 a	9.33 b	10.60	66.66 a	142.80 a	3317.4 ab	11.97 ab	33.15 bc	20.02
Adasoy	36.90 b	10.33 ab	10.46	70.72 a	141.33 a	3030.2 bc	11.24 bc	35.44 a	19.90
LSD	6.09	1.36	3.96	10.92	19.06	586.5	2.16	1.71	1.34

In each column, means followed by the same letter within columns are not significantly different (P < 0.01) according to Tukey test

Among the soybean genotypes, the lowest plant height was obtained with the Lider genotype (36.82 cm), while the other genotypes were in the same group and had plant heights varying between 42.65 cm and 49.09 cm (Table 2). According to their variance analysis of the plant height values of different soybean genotypes, Gaffarogluyetgin (2008) determined that the differences among the genotypes were significant. It has been reported that plant height of soybean can range from 30 cm to 150 cm, depending on the variety, sowing time, row spacing and growing conditions (Arioglu, 2007).

Arıoglu et al., (2015) found that first plant height was between 103.3 cm and 137.9 cm and Senyigit et al., (2015) determined that it varied between 82.2 cm and 108.9 cm. The differences between the plant heights of soybean genotypes are attributable to the genetic structures of the genotypes and the different effects of environmental conditions on the genotypes. In addition, soybean crop is a short-day plant and thus, due to the shortening of days after June, the short-day conditions are effective in the sowings during the last week of June; therefore, the vegetative growth of soybean decreases and, consequently, plant height remains short. In their study under main crop and second crop conditions, Cinsoy et al., (2005) reported that plant height shortened as sowing time was delayed.

The highest first pod height was obtained with the Bravo variety with 11.0 cm, while the Türksoy (9.33 cm) and Lider (9.40 cm) genotypes had the lowest first pod height values. Soybean agriculture is negatively affected if the pods are close to the soil surface. This is because the pods that are close to the soil surface cannot be harvested, which leads to substantial harvest losses (Arslanoglu et al., 2005; Yilmaz et al., 2005; Beyyavas et al., 2007; Ilker, 2017). In their study in which the effects of growing time on certain agronomic properties and quality of soybean were investigated, Bakal et al., (2017) found that the mean first pod height under main crop conditions was 19.3 cm, while it was 17.9 cm under second crop conditions. In the growing of soybean as the main crop, long-day conditions affect the vegetative growth, while in its agriculture as an second crop, short-day conditions are effective (Bakal et al., 2017). In the sowings after June 21, due to the high mean temperatures and the effects of short-day conditions, the plants start to flower shortly after emergence and, therefore, the first pods are closer to the soil (Arioglu, 1999). Thus, first pods are desired to be higher above the soil surface. There were insignificant differences between the genotypes in terms of node number (Table1). The node number values varied between 7.66 and 11.60 nodes. Node number differs depending on whether the genotypes are early-maturing or late-maturing (Gunes, 2006). There were statistically significant differences in the pod number values of the genotypes. The highest pod number values were obtained with the Adasoy (70.72 pods) and Turksoy (66.66 pods) genotypes, while the Bravo (32.60 pods) variety had the lowest pod number. In soy, pod number is closely related to yield and, thus, it is desired to be as high as possible. Pod number changes depending on the sowing time and genetic structure of the genotypes (Yaver and Pasa, 2009). Various cultivation applications (plant density, irrigation, fertilization, etc.) are thought to affect the pod number of soy. The results obtained in the study are attributable to climatic and genotypic factors. There were statistically significant differences in the seed numbers of the plants. The highest seed number per pod values were obtained with the Adasoy (141.33 seeds) and Turksoy (142.80 seeds) (2.78 seeds pod^{-1}) genotypes, while the Bravo (68.54 seeds) variety had the lowest seed number per pod. In another study, the researchers reported that the seed number per pod values of the genotypes were different from each other and the Nova and Umut genotypes (2.83 seeds.pod^{-1}) had the highest seed number per pod values (Boydak et al., 2018). There were statistically significant differences between the genotypes in terms of seed yield and the highest seed yield was obtained with the Asya (3762.5 kg ha^{-1}) variety, while the Bravo (2325.7 kg ha^{-1}) variety had the lowest seed yield. The results obtained in this study agree with the results obtained in other studies that were carried out under the second crop conditions in Turkey (Yilmaz et al., 2005; Beyyavas et al., 2007; Arioglu et al., 2012; Caliskan et al., 2007; Sarimehmetoglu and Arioglu, 2008; Ilker, 2017). The Asya (13.96 g) variety had the highest 100-seed weight, while the lowest 100-seed weight value was obtained with the Bravo (8.63 g) variety. The differences between the 100-seed values are attributable to different climatic conditions, maintenance techniques and genetic traits. The results agree with the results obtained in other studies carried out under the second crop conditions in Turkey (Yilmaz et al., 2005; Beyyavas et al., 2007; Karaaslan, 2011; Ilker, 2017).

According to the variance analysis of the crude protein contents of the soybean and genotypes, the differences between the crude protein contents of the lines and genotypes were statistically significant (Table 1). The Adasoy (35.44%) variety had the highest protein content, while the lowest protein content was obtained with the Nazlican (32.59%) variety. The differences in protein contents were attributed to the different genetic structures of the genotypes. The differences among the genotypes in oil rate were not statistically significant and the oil content of the soybean genotypes varied between 19.90% and 21.23% (Table 2). The differences among the genotypes were due to the "genotype x environment" interaction. The highest oil content was obtained with the Arisoy and Blaze genotypes with 23.83% and 22.86%, while the oil contents of other genotypes were in the range of 20.16-20.66%. Hu (2013) found that the sowing time did not affect the oil content. Other researchers reported that the delaying of sowing caused decreases in the oil content (Kumar et al., 2006; Tremblay et al., 2006), which is in contrast to the results found in this study, while Daneshmand et al., (2013) reported that the highest oil content was obtained when sowing was delayed. In their study, Gulluoglu et al., (2010) determined that the oil content of soy differed depending on the variety and the results of their study is different from those reported in studies that were carried out under second crop conditions in Turkey (Bakal, 2017; Sogut et al., 2005; Yilmaz et al., 2005; Beyyavas et al., 2007; Karaaslan, 2011; Arioglu et al., 2012; Ilker, 2017).

Conclusion

The study showed that soybean can be grown as an alternative to other products in the irrigable farm lands of Şırnak. Furthermore, considering the global average soybean yield of 2490 kg ha^{-1} the presence of soybean and genotypes with a yield twice as high as that of the global average is an indicator of its suitability for agriculture in Turkey. As revealed by the results of the study, the yield values of the researched soybean genotypes ranged from 2325.7 kg ha^{-1} to 3762.5 kg ha^{-1} and the highest seed yield were found with the Asya (3762.5 kg ha^{-1}) and Türksoy (3317.4 kg ha^{-1}) genotypes. The Adasoy variety had the highest protein contents. It was concluded that the investigated genotypes can be successfully grown under the second crop conditions in Şırnak.

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Consumers' willingness to pay for organic agriculture products: a case study of Nepalgunj city, Banke

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Abstract

This study was carried in Nepalgunj Sub-Metropolitan City, Nepal to understand awareness of consumers' about organic product, consumers' willingness to pay for organic products and socio-economic factors affecting their decision of willingness to pay for consumption of organic goods. Total of 200 respondents were selected as sample population. Among total respondents, 85.5% of respondent were aware about organic products, among which only 53% respondents were well informed about organic products and their importance. Out of 200 randomly selected respondents only 114 respondents were willing to pay addition cost or price premium for organic products. Among ten socioeconomic variables listed only seven variables found to be determinant of willingness to pay premium price for organic agricultural products, which are gender, occupation, income level and education of respondents, and awareness about chemical residue absence in organic agriculture products, perception of higher nutrition on organic products and awareness about health benefit from organic products. Result showed that income level and health consciousness are two most important determining factor. So, there is a need to find a way so that more and more people can be made aware about organic agricultural products and provide organic products at reasonable price premium.

Keywords: Consumer preference, Organic agriculture, Socioeconomic, Willingness to pay

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Introduction

Organic farming is the form of production and management system that avoids or excludes the use of synthetic chemical inputs or genetically modified organisms and focus on utilizing natural resource and management system. Organic farming gives importance to environmental preservation, protection and human health (Meena et. al., 2013). Organic farming is a form of agricultural production practice where chemicals are not used on crops from planting to the final consumption. It is an environment friendly production management system that aims to protect and improve biodiversity and environment as well as human health (Behera et. al., 2012). And, product of such production management system is known as organic products. Our current modern agriculture system is heavily influenced and dependent upon large amounts chemicals and synthetic products such as fertilizer, pesticide, growth hormone etc., which causes increase in cost of production and at the same time harms environmental quality and human health. Such increased large scale use of chemical products lead to the increase in extent and rate of several diseases such neural diseases, cancerous infection, body disorders etc. With the increase in occurrence of such life threatening diseases, world is moving toward increasing healthier and quality food (Rock et al., 2017a). The search of more sustainable, balance and healthier farming system, led to the organic farming. It not only helped to lower cost of production and minimization of environmental degradation also improvements of human health (Worthington, 2001).

There is increasing demand for organic production throughout the world especially in developed countries mainly due to health issue. But, we cannot forget that demand is always dependent upon price of the commodity. Generally output production level of organic production system is considered to be lower in comparison to inorganic farming system (Issaka et. al., 2016). Due to that reason, production, productivity, profitability and market competition has become significantly important issue on the discussion of food security and organic farming, especially in developing nation like Nepal. Nepal is developing nation with significantly lower per capita income (Shrestha and Baral, 2018a), so we cannot overlook production cost and purchasing cost as well. Ponti et. al. (2012) reported on an average general production level of organic farming is 20% less in comparison to inorganic farming system. Savage (2015) reported that on an average 89% of organic cultivated land shows lower productivity in comparison to inorganic farming. So lower productivity directly implies higher per unit cost of production and higher price for consumer.

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Nepal is a developing nation with lower per capita income, so price level obviously serves as an important decision factor for organic product consumption. So, this study was carried in Nepalgunj Sub-Metropolitan City, Nepal to understand awareness of consumers' about organic product, consumers' willingness to pay for organic products and socio-economic factors affecting their decision of willingness to pay for consumption of organic goods.

Materials and Method

Study Area

This study was conducted in Nepalgunj Sub-Metropolitan City, Banke, Nepal. It lies in terai belt near southern board of Nepal. It is capital of Banke District and oldest market of western Nepal. This area was particularly chosen because of availability of all range of organic to inorganic, cheap to expensive food products due to closeness of Indian boarder. This is the first research of Nepal that has been carried to understand willingness to pay for organic products.

Sample Size, Sampling Procedure and Selection of Respondents

For the study, total of 200 respondents were selected as sample population. Of which 25 respondents were randomly selected from home visit and remaining 175 respondents were randomly selected from vegetable and food market of the city. Due to economic and manpower limitation such limited number of respondents were selected for study.

Source of Information

For primary data pretested systemic semi-structured questionnaire was used for face to face interview of consumers and key informant interview. As only primary source of data cannot be used for overall data collection and verification (Shrestha, 2018), several other means of resources were also implied. So that, several books, reports, article and other publications published by Government of Nepal, several research institutes, newspaper articles and publication of several NGOs were used as source of secondary information.

Data Collection and Analysis

The field survey and key informant interview for the study was conducted in July, 2018. Two different set of questionnaire were prepared for respondents and key informants. The respondents were interviewed using face to face method by visiting their homes. Key informants were interviewed in the same manner. Information obtained from the interview was crosschecked through key informants (Shrestha et. al., 2018). Collected data were coded, tabulated, summarized and analyzed for determination and interpretation. Microsoft Excel and STATA 12 were used for analysis purpose.

Socio-economic Factors Affecting Willingness to Pay

To estimate or analyze socioeconomic factor affecting willingness to pay for organic products Logistic regression was used, due to binary nature of dependent variable. Logistic regression is used to determine the relationship between several socioeconomic variables and willingness to pay of respondents (Shrestha and Baral, 2018b). After key informant interview, focus group discussion and some reviewing, several socioeconomic factors such as gender and education of household head, occupation, annual income etc. were used as independent variable to estimate their effect on willingness to pay for organic products.

The binary Logit regression model can be expressed as;

$Y_i = f(\beta_i x_i)$ = f (Age, Gender and Education of HH head, Occupation, Family size, gender and education of household head, occupation, annual income, availability etc.). Other details and value about variables are presented in Table 1.

Table 1. Description of the variables used in the Logit model

Variables	Description	Value
Age	Age of Respondent	Number of Years
Gender	Gender of Respondent	Female=0, Male=1
Education	Education of Respondent	Number of Years
Occupation	Major family occupation	Other=1, Agriculture=0
Total size	Number of family members	Number
Income	Monthly income	Less than 50,000= 0 More than 50,000= 1
Chemical	Consumers knowledge about absence of chemical in organic product	No=0, Yes=1
Taste	Consumers perception about better taste of organic product	No=0, Yes=1
Nutrients	Consumers perception about better nutrition of organic product	No=0, Yes=1
Health	Consumers perception about better health with organic product	No=0, Yes=1

Result and Discussion

Consumers' Knowledge of Organic Products

Among total respondents, 85.5% of respondent were aware about organic products, which is on par with the report of Rock et. al. (2017b). Of which 53% respondents were very clear about organic products and their importance, 23.5% respondent were ambiguous about organic products and 9% respondents had only limited knowledge about organic products. Among total respondents, major source of information about organic products and their importance found to be media sources such as social media, FM, TV, Newspaper etc. Details of awareness and source of information are presented in Table 2.

Extent of Willingness to Pay

Out of 200 randomly selected respondents only 114 respondents (57%) were willing to pay addition cost or price premium for organic products. This is very low in relation to report of Vapa-Tankosic et. al. (2017). Among those willing consumers, majority of them are willing to pay additional 10% for organic products, which makes for 46.49% of total willing consumers. With the increase in price premium, number of willing consumers keep declining. This indicates that majority of willing consumers are willing to pay price premium only for limited extent. This indicates that price premium hinders consumers' willingness to pay for organic product (Sriwaranun et. al., 2015). Detail of this distribution is presented in Table 3.

Table 2. Awareness of organic products

Characteristics	Frequency	Percent
Awareness of organic products		
Well informed	106	53.0%
Little ambiguous	47	23.5%
Little information	18	9%
Not informed	29	14.5%
Major source of awareness		
Media	101	50.5%
NGO/INGOs	9	4.5%
School	23	11.5%
Family member	22	11%
Neighbor/colleges	16	8%

Table 3. Extent of Willingness to Pay

Extent of Pay	Frequency	Percent (Among willing consumer)	Percent (Total respondents)
Up to 10%	53	46.49%	26.50%
10 - 15%	31	27.20%	15.50%
15- 20%	24	21.05%	12.00%
> 20%	6	5.26%	3.00%
Total	114	100%	57%

Socioeconomic Factors Affecting Willingness to Pay

Among ten socioeconomic variables listed only seven variables found to be determinant of willingness to pay premium price for organic agricultural products. Gender and education of respondents, and awareness about chemical residue absence in organic agriculture products found to be significant at10%level, while occupation of respondents and perception of higher nutrition on organic products found to be significant at 5% level. Similarly, income level of respondents and awareness about health benefit from organic products found to be significant at 1% level. Further details are presented in Table 4.

Table 4. Determination of Willingness to Pay

Variables	dy/dx	Std. Err.	p> |z|	
Age HH	-0.0544	0.0814	0.404	
Gender#	0.0275	0.0091	0.051	*
Education	0.0131	0.0083	0.053	*
Occupation #	0.0912	0.0328	0.032	**
Size	-0.0156	0.0251	0.534	
Income#	0.2143	0.0451	0.003	***
Chemical#	0.1232	0.0756	0.062	*
Taste#	0.2131	0.2431	0.336	
Nutrition#	0.1328	0.0867	0.042	**
Health#	0.3214	0.0653	0.002	***

***, ** and * indicates 1%, 5% and 10% level of significance respectively.
(#) dy/dx is for discrete change of dummy variable from 0 to 1.

Result showed that, probability of willing to pay premium price for organic products is increased by 2% for male respondents in comparison to female respondents. This is opposite of what Rani et. al. (2018) reported, as they suggested that there is no significant relation between willingness to pay and gender of consumer. It is also visible in result that increase in education by 1 year can increase probability of willingness to pay by 1.31%. This result is supported by findings of Rani et al., (2018), as they suggest that increase in education level has positive relation with willingness to pay for organic agriculture products. Similarly, awareness about chemical residue absence in organic agriculture products can increase the probability of willingness to pay by 12.32%. It has been observed that, there is strong and positive relation between consumers' willingness to pay with awareness about chemical residue and uses in agricultural products (Owusu and Anifori, 2016).

Result showed that, respondents involved in occupation other than agriculture have higher probability of paying premium price for organic agricultural products, i.e. 9.12%. Similarly, people who perceives organic products are more nutritional compared to normal agricultural products, have 13.28% more probability of willing to pay premium price for organic products. This finding is supported by Rani et al., (2018). Madhavaiah and Shashikiran (2015) stated that willingness to pay for organic agricultural products are outcome of several socioeconomic factors of individual concerning their occupation, income, lifestyle and awareness and perception toward organic products.

Result showed that people with the income more than NRs. 50,000 have 21.43% more probability of willingness to pay premium price for organic agriculture products. Similarly, people who perceive that organic agricultural products ensure better health are 32.14% more likely to pay premium price for organic agricultural product. This finding shows that most important factor determining willingness to pay for organic agriculture products are income level of people and their conscience toward health and importance of organic products (Amirnejad and Tonakbar, 2015).

Conclusion

There is increasing demand for organic production throughout the world especially in developed countries mainly due to health issue. But, we cannot forget that demand and supply both heavily relies upon price of the commodity. Specially for developing nation like us, price possesses as significant determinants of demand of product. This study proves that there is general concern among significant amount of population about organic agricultural products and health advantages associated with it. This study reveals that more than half of population are willing to pay premium price for organic products, provided limited price addition. This study shows that willingness to pay has significant and adverse relation with price of organic products. Study showed that 53% of population are well informed about organic products and their importance. Study shows that about 51% of population received awareness about organic products through media source, indicating reach and strength of the media to enhance and improve awareness programs. Study showed that most important factor determining willingness to pay are income level and consumers' awareness regarding health advantages associated with climate change. So, there is a need, to be find a way so that more and more people can be made aware about organic agricultural products and provide with reasonable price premium.

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Is it true that the date palm tree consumes a lot of water? Evaluation of the date palm tree transpiration using Granier's sap flow method in a Tunisian Saharan oasis

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Abstract

To improve the irrigation water management in oasian context, evapotranspiration assessment is required. In Tunisian oases, date palm (*Phoenix dactylifera* L.) is the main crop and its water use is an essential evapotranspiration element. In this research, sap flow measurement was implemented to assess the date palm transpiration inside an irrigated-drained field within which the shallow-groundwater level and the water balance elements were continuously monitored. The site is a Tunisian Saharan oasis, stamped by waterlogging and salinity manifestation and by low-frequency and irregular flooding irrigation. The cropping system is two-storey palm/grass layered system. This paper focuses on one-year period sap flow measurements using a recalibrated Granier's TDP-method. Results showed that the instantly transpiration varied with the air temperature and was high related to the shallow water table nycthemeral fluctuation. The daily transpiration ranged between 0.5 and 3.5 mm d^{-1} with a clear seasonal variation. A water stress appearance according to water delivery frequency during the summer season was also revealed. The one-year-cumulated date palm transpiration was about 730 mm and represented almost 60% of the overall oasis deduced evapotranspiration. From this experiment case, it was noted that the date palm tree transpiration reflect a modest water consumption (35 to 45%) relatively to the surrounding high evaporative demand and it can be deduced that date palm tree, in itself, isn't a great water consumer in such cropping conditions. After more validation, these elucidations should be considered to rethink the date palm irrigation scheduling and the water management practices inside oasis schemes.

Keywords: Date-palm (*Phoenix dactylifera* L.), Sap flow, Transpiration, Saharan oasis, Tunisia

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Introduction

The irrigation water management and its rational use in arid and hyper-arid zones, such as oases context, requires an accurate quantification of the different water balance terms, including canopy transpiration reflecting the net crop water-consumption (Brunel et al., 2006). This knowledge is crucial to sustain a balanced functioning of a date palm oasian agro-system knowing a continuous enlargement in many hyper-arid regions of the world as in the North-African Saharan zone, posing thereby many challenge aspects, agro-socioeconomic and hydrological, very dependent on environmental, climatic and soil conditions (Sellami, 2008; Bouarfa et al., 2009; Mekki et al., 2013). Establishing exhaustive water balance and assessing evapotranspiration inside oasian schemes is thereby a key task to optimize the water use efficiency and to sustain water resources, especially if water is scarce, expensive and brackish as in most Tunisian Saharan oases (Sellami, 2008; Bouarfa et al., 2009; Mekki et al., 2013; Ben Aïssa et al., 2013; Hachicha and Ben Aïssa, 2014; Omrani, 2015).

The scientific efforts invested in this research topic are relatively recent for oasian context and, given their still too narrow analysis, spatially and temporally, haven't far served as an effective aid to decide on a more efficient water management inside date palm groves (Carr, 2013). Scientific research must, thus, invest in both ever more relevant methodological approaches and more useful modeling. Requiring deeply studies and research (Al-Muaini et al., 2019), it's clear that, depending of the biological aspects determining the date palm yield and the fruit quality, the transpiration constitutes an indispensable indicator to put in relation with the production factors and the local water quality and management constraints (Zhen et al., 2019).

Numerous methods and approaches are used to estimate crop evapotranspiration at different scales. For continuous-cover crops, the choice is so large. However, for sparse crops or row-cropped trees, like palm groves, orchards and forest

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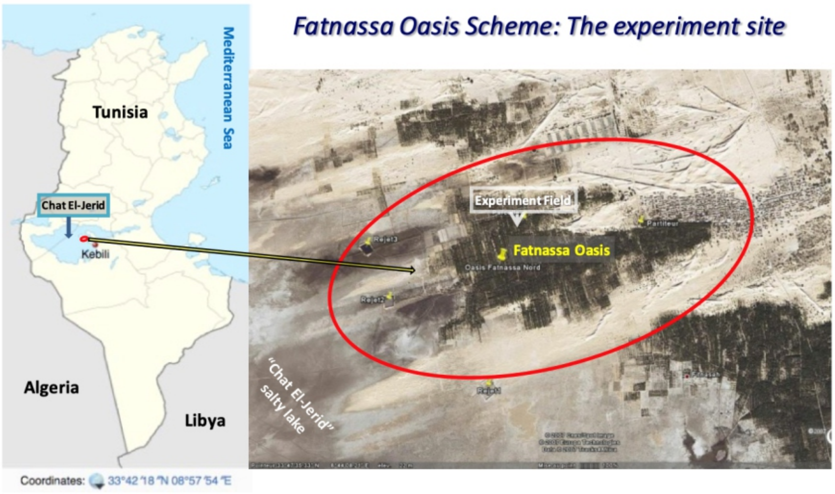
stands with sampling and representativeness problems, adequate methods are few (Granier, 1985). Among these methods, sap flow measurement is widely referenced for direct whole-tree transpiration assessment and several thermal methods are developed and used since some thirty years (Poyatos et al., 2016). The trunk sap flow measurement has been validated to monitor in situ trees' transpiration at different ecosystems such as savannahs (Do and Rocheteau, 2002b), forest stands (Granier, 1987; Köstner et al., 1998), fruit orchards (Cabibel et al., 1991b; Ben Aïssa et al, 2000), tropical palms (Dufrêne et al., 1992; Roupsard et al., 2006; Madurapperuma et al., 2009), date palm groves (Ringersma et al., 1996; Sellami and Sifaoui, 2003; Sperling et al., 2012; El-Khoumsi et al., 2017; Al-Muaini et al., 2019). It has the advantage to integrate roots and canopy heterogeneities through the trunk as a unique pathway of ascending water (xylem crude sap) respecting the soil-plant-atmosphere continuity.

As a contribution to these scientific investigations, we conducted this experiment aiming to apprehend the water balance inside an oasian cropping system with a particular focus on the date palm transpiration as a key component. In Fatnassa' date-palm grove, our oasian experiment site for several years (Ben Aïssa et al., 2005), we tried to assess and analyze the water balance, in connection with irrigation depth and frequency, inside an irrigated-drained field reflecting overall the water management complexity within the oasis (Ben Aïssa et al., 2013). In this paper, some results relating to the date palm sap flow magnitudes and variation are presented with the monitored water balance components (irrigation, drainage, water-table fluctuation, water salinity),. Among the several developed and used sap flow thermal methods, the Granier's thermal dissipation probe (TDP) technique, known for its simplicity and convenience for continuous measurements (Fuchs et al., 2017) was selected and applied for the experiment of this study.

Materials and Methods

Experiment site: context and specificity

The Fatnassa oasis scheme (33°,8N; 8°,7E), located in the north side of the Nefzawa Tunisian Saharan oases region, with about 150 hectares of irrigated area, was chosen as site to conduct this experiment (Picture1). This oasis, right-on the edge of a big salty lake called "Chat El-Jerid", is prone to waterlogging and salinity manifestations with a rather unfavorable water availability compared to many other oases in the region (Ben Aïssa, 2006; Hachicha and Ben Aïssa, 2014).



Picture 1. Geographic location of the experiment site
(Left: Map of Tunisia ; Right: satellite photo of the oasis from Google Earth on 2007)

The climate is continental Saharan, with high daily and seasonal thermal amplitudes and irregular yearly rainfall less than 100 mm. The mean potential evapotranspiration is about 1800 to 2000 mm yr^{-1} and the water deficit is continuously high overall the year (Floret and Pontanier, 1982). The soil inside the oasis is mostly gypsiferous or gypseous fine sand regenerated from eolian deposit of gypsic aridisoils active dunes. These soils, poor structured, are known by their instability, their rather high porosity and their weak water retention capacity. Some characteristics of the study site soil are presented thereafter (Table 1).

The experiment field consists of a 0.8 hectare plot containing 20-year-old "Deglet Nour" date palms planted in a 200 trees per hectare (7m per 7m) density. The average palm-trees height within this plot is ~8 m. The low canopy layer, underlying the palm-trees, consists mostly of sparse fodder and alfalfa crop almost renewed every 3 years (Picture 2).

As in most Tunisian oases, the irrigation water coming from deep fossil groundwaters is distributed in concreted channels and provided to farmers' plots in water turn. On the field, the water supply is carried out by total surface flooding. Its frequency in the experiment field, observed by continuous monitoring, is almost monthly with some turn irregularities, especially in summer season due to the high water demand and water scarcity (Ben Aïssa, 2006). At the approach of winter, the water turn is more regular; given the decrease of the crops water needs but also because of the farmers' voluntary irrigation reduction while the harvest season.

The drainage is deficiently assured by a subsurface PVC pipes system prone to mineral and root clogging (Ben Aïssa et al., 2013). The shallow saline water-table regenerated by irrigation with cyclic presence events near the soil surface is in close interactions with the soil, the crops and the different water and salinity management practices (irrigation, drainage, pumping etc.). The shallow groundwater table is thereby in a high dynamic and its fine-scale level monitoring constitutes an important tool to apprehend the hydric functioning within a groundwater-soil-plant-atmosphere continuum (Ben Aïssa et al., 2013).

Moreover, the low soil water retention capacity and the low irrigation frequency confer a determining contribution of the shallow water-table in the water supply for the grown crops (date palm and fodder), well known for their developed root system and their salinity and gypsum tolerance (Ayers and Westcott, 1985). In such context, the practice of irrigation corresponds *de facto* to manage the shallow water table with high capillary rise than to maintain a weak useful reserve in a high macro-porous gypseous sandy soil.

Sap flow measurement and calculation

On-the field installation plan and handling

During this experimental work, on-the field sap flow measurement has been performed in accordance with Granier's heat dissipation method (Granier, 1985; 1987) recalibrated for tropical palms by Roupsard et al. (2006). Four neighboring fully-grown date palm trees (square mesh 7 x 7 m²) of the "Deglet Nour" variety were equipped with sap flow sensors. The locally-made sensors (TDP type) used in this experiment, having 20 mm in length and 2 mm in diameter, were manufactured according to Roupsard et al. (2006) prescriptions. As a result, the sensors are almost identical and accept the same calibration and calculation equations as that elaborated and validated by these authors. The heating voltages, provided by rechargeable battery, were regulated to have continuously a 200 mW constant power at each heated probe. Following a failure at one of the power-regulator output terminals, one of the singular sensors was left permanently without heating while recording its signal. The sensor signals were logged by a CR10x data logger via an AM416 multiplexer (*Campbell Scientific*) at one minute steps and averaged every 15 minutes. The data recovery was performed periodically using a laptop PC.

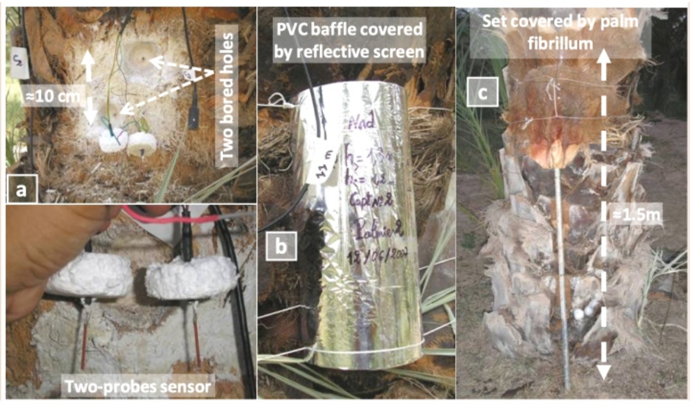
Given the date palm trunk thickness and hardness, some methodological adaptations about the installation and the insulation were however implemented compared to that prescribed by Roupsard et al. (2006) on Coconut palm. Indeed, on each palm tree, the sensor probes were installed at ~8 cm depth radially into the trunk North-direction side and at 1.5 m height above ground. Since we used 2 cm length probes, to reach the trunk sapwood, we performed 5 cm diameter and 6 to 8 cm depth holes using hole saw and wood chisel and without removing the old leaves pruned stubs traditionally left on the stem. At the bottom of each hole, it was drilled, using a 2 mm wick, 20 mm depth again to insert fitly the probes. After probes insertion, the wide bored holes were insidely masticated and then sealed with polystyrene cylinders to avoid sapwood desiccation (Picture 3, a). Each sensor was protected from direct sunshine by a PVC baffle covered by a reflective screen (Picture 3, b). For a better protection, the sensor set was finally well-covered with palm fibrillum to give the same color as the trunk. (Picture 3, c).

Table 1. Some soil characteristics in the studied field

Soil horizon (cm)	% Clay	% Silt	% Fine sand (0,05-0,2 mm)	% Medium sand (0,2-0,5 mm)	% Coarse sand (0,5-2 mm)	Gypsum (%)	Bulk density	Porosity (%)	θ_{fc} (%)	θ_{wp} (%)
0-20	4	6	72	13	5	70	1.13	32	15	5
20-40	5	6	71	14	4	67	1.15	28	16	5
40-60	5	7	72	12	4	62	1.18	25	15	6
60-80	6	8	73	11	2	55	1.21	22	13	5
80-100	6	8	76	10	0	52	1.25	20	13	6

(*) Horizons, deeper than 100 cm, are saturated in water because of the shallow water table level while sampling

Picture 2. Deglet Nour date palm trees inside the experiment field (Photo taken by I. BEN AISSA)



Picture 3. Details of the TDP Sap flow sensor installation on the date palm trunk with adopted insulation precautions (Photos taken by I. BEN AISSA)

Granier's TDP sap-flow calculation: a brief theory overview

The measurement principle is a convective cooling, due to the circulation of the sap, of a heated probe at constant power (Granier, 1985). The sensor consists of two cylindrical needles containing Cu/Cs thermocouples mounted in opposition. They are inserted radially into the stem sap-wood containing the xylem bundles ensuring the

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crude-sap ascension. A gap of about 10 cm separates the heated needle (high) from the second needle (low) monitoring the reference trunk temperature below the heating point. The decrease in the temperature difference (ΔT) between the two needles is related to the flux density or sap velocity calculated by an empirical formula based on two sap flow conditions:

(i) at zero sap flow, we record a temperature difference called ΔT_{ref} or ΔT_{max} and

(ii) with non-zero sap flow, we record a temperature difference called ΔT

These thermal differences will be the basis for calculating the flux density () written as follows:

$$\phi = \alpha.(K)^{\beta} \quad (1)$$

where ϕ is the sap flux density ($m^3\ m^{-2}\ s^{-1}$) or also sap velocity ($m\ s^{-1}$), α and β are two calibration coefficients and K is a dimensionless term called the Flow Index and calculated as follows (whith, ΔT_{max} and ΔT_{ϕ} are the same parameters mentioned above):

$$K = \left[\frac{\Delta T_{max} - \Delta T_{\phi}}{\Delta T_{\phi}}\right] \quad (2)$$

Date-palm sap-flux density calculation

The sap flux density is calculated from an empirical model established for forest species (Granier, 1985, 1987) and fruit trees (Cabibel et al., 1991b). On palm trees (oil and coconut palms), Roupsard et al. (2006) recalculated α and β adjustment coefficients after a locally-made probes calibration in the laboratory and validated in a coconut palm field by comparison to the eddy covariance fluxes. The new adopted coefficients are 315.10^{-6} and 1.231 for α and β respectively, and we write:

$$\phi(m\ s^{-1}) = 315.10^{-6}.(K)^{1.231} \quad (3)$$

For this experiment, since we used the same locally-made probes as Roupsard et al. (2006) with the same heating power (200 mW), the same α and β equation coefficients were adopted (Formula 3) without further probes calibration. After a sensors installation tuning, in particular concerning the needles insertion depth and insulation, the preliminary recorded signals from the heated sensors evolve coherently with rather synchronous kinetics but, nevertheless, with differences in ΔT_{max} and ΔT_{ϕ} offsets and amplitudes. The ΔT_{max} values vary from day to day and differently for each sensor. Therefore, the consideration of a main ΔT_{max} on ten days envelope as mentioned by Granier (1987) seemed to be a supplemental source of error (Rabbel et al., 2016). Thus, to compute the flux index over a day we considered ΔT_{max} recorded during the two nocturnal periods, preceding and succeeding the diurnal period of the considered day.

Date-palm transpiration assessment from sap-flux density

From the above formula, the total sap flow (*Sf*) passing through the stem is estimated as follows (where *Sc* is the sap-conducting (sapwood) section area, estimated in m²):

$$Sf(m^3 s^{-1}) = \phi.Sc \quad (4)$$

For *Sc* calculation, an investigation has been conducted through observations of many fresh cuts made on date-palm stems in the oasis. This appreciation has been performed in other similar works on palm stems (Dufrêne et al., 1992; Ringersma et al., 1996; Sellami and Siffawi, 2003; Roupsard et al., 2006). For more accuracy, some recent studies (Sperling, 2012; Fathi, 2014) tried to differentiate a radial conduction variation inside the date-palm stem but the results are various. For our case, visual observations lead us to consider, in a simplification trend, that the whole white-colored sapwood section is uniformly sap conductive. A cut of a "Deglet Noor" palm trunk (having the same age and size as the studied trees) lead to estimate, through difference in color, that *Sc* is about 7 dm², representing ~52% of the total stem section area (Picture 4).

At a tree-scale, the measured sap-flow is expressed as:

- Hourly sap-flow ($L\ h^{-1}$); this expression is used to characterize and compare the actual and nycthemeral sap flow kinetics.
- Daily cumulated sap-flow ($L\ d^{-1}$); which corresponds to the daily transpiration expressed in ($mm\ d^{-1}$) on an area basis. For this, given the date palm plantation density within the experiment field, a relative occupation area of ~50 m² is allocated for each tree.

In order to extrapolate transpiration from tree-scale to field-scale, we have considered via simplification that the studied palms (equipped with sap-flow sensors) are representative of the whole field. The studied trees have nearly the same trunk perimeter of about 130±2 cm. From where, we estimate a daily transpiration (*Tp*), at the field-scale, by the following equation:

$$Tp\,(mm\ d^{-1}\ or\ kg\ m^{-2}d^{-1}) = \sum_{t=1}^{24\,h}(Sf.3600)\frac{N}{10000}.10^{-3} \quad (5)$$

where *Sf* is the single-tree sap flow ($m^3\ s^{-1}$) calculated by meaning measurements made on three palms, *N* is the number of palms per ha of field area ($N \approx 200$ trees per hectare).

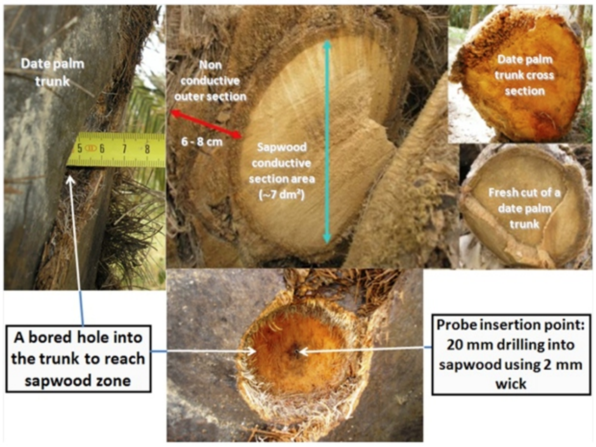
Climatic parameters

Given the lack of an in situ weather station, we tried to ensure an under-palm-canopy air temperature monitoring using a Cu/Cs thermocouple, lodged inside a ventilated box and logged by the same CR10x at the same time step as the sap flow. Moreover, the under-palm-canopy air temperature and relative humidity were also, but irregularly, half-hourly logged at 1.5 m height above ground using an EL-USB2 Lascar's sensor nearby the instrumented trees.

For above-canopy meteorological investigations, the daily climatic data, relating to the region in which the studied oasis is located, were furthermore collected from a governmental weather station located at Kébili city, about 20 km straight far from the experiment site.

Water table level, water and salt balances monitoring

The shallow water-table level was continuously monitored at two hand-augered observation wells dug between the field boundaries and the unique drain pipe crossing the field. A barometric-compensated pressure sensor is immersed, at each observation well, in the water table to monitor its level fluctuation. The details of all the devices installed in the field to monitor water table level, irrigation and drainage are well described by Ben Aïssa et al. (2013).



Picture 4. Cuts on date palm trunks to investigate the conductive sapwood area and to identify the Sf probes insertion depth (Photos taken by I. BEN AISSA)

Results and Discussion

Hourly sap flow variation with the under-canopy measured air temperature

The Figure 1 illustrates the hourly averages calculated from 14 days continuous measurement series related to air temperature; *Ta* (°C), and to sap flow; *Sf* (L h^{-1}) during the summer season (233 to 246 DOY). During this period, *Ta* varied from 25 to 48°C characterizing a high evaporative demand. From these hourly rates (averaged from 15min step records), we can perceive that *Sf* curves (of two presented palms) are fairly synchronous and very close during this period of measurement. The maximum hourly flow values, observed in the middle of the day, ranged between 12 and 17 L h^{-1} corresponding to 1.7 and 2.4 L dm^{-2} h^{-1} of flux densities. At this hourly time-scale, the figured courses shows a close relation between *Ta* and *Sf*. This concordance seems however less clear on a daily time-scale.

The comparison of the hourly averages during two days with contrasted weather conditions shows, that during the summer season (Figure 2, a), the air temperature is maximum two hours after the sap-flow reaches its maximum and it then decreases much less rapidly. This is can be explained by the fact that *Sf* (or transpiration) is a physiological phenomenon related also to the intercepted solar radiation, to the vapor pressure deficit and to the plant water status controlling together the stomata regulated opening and the water loss from leaves to the atmosphere. While *Ta*, pure physical, is influenced by the surrounding environment thermal inertia from where its evolution is slower than *Sf*. In winter season (Figure 2, b), the hourly kinetics are more synchronized or showing a small delay of the sap flow compared to the temperature with much lower maximum values than in summer. But, we have to indicate that *Ta* presented on these figures was measured under palm canopies and it can thereby be influenced by shading.

The day-night shallow water table fluctuation as related to the transpiration activity

On the figure 3, The curves of the instantaneous date-palm sap-flow and the fine-measured water table level evolving during 10 summer season consecutive days (236 to 245 DOY) succeeding an irrigation event, are presented. On the water table level curve, a day-night oscillation is clearly noticed during the groundwater table drawdown phase. This nycthemeral shallow groundwater level fluctuation is characterized by a faster diurnal drawdown than during nocturnal period. This fluctuation was assumed by many authors to be directly related to the phreatophytes evapotranspiration activity and magnitude (Loheide II et al, 2005). In our experiment field, the evapotranspiration outflow, occurring during the diurnal phase, is added to the drainage and downstream outflows, resulting thereby in a faster diurnal drawdown. During the nocturnal phase, evapotranspiration is almost zero and only drainage and downstream outflows which continue to drive the water table drawdown (Ben Aissa et al., 2013).

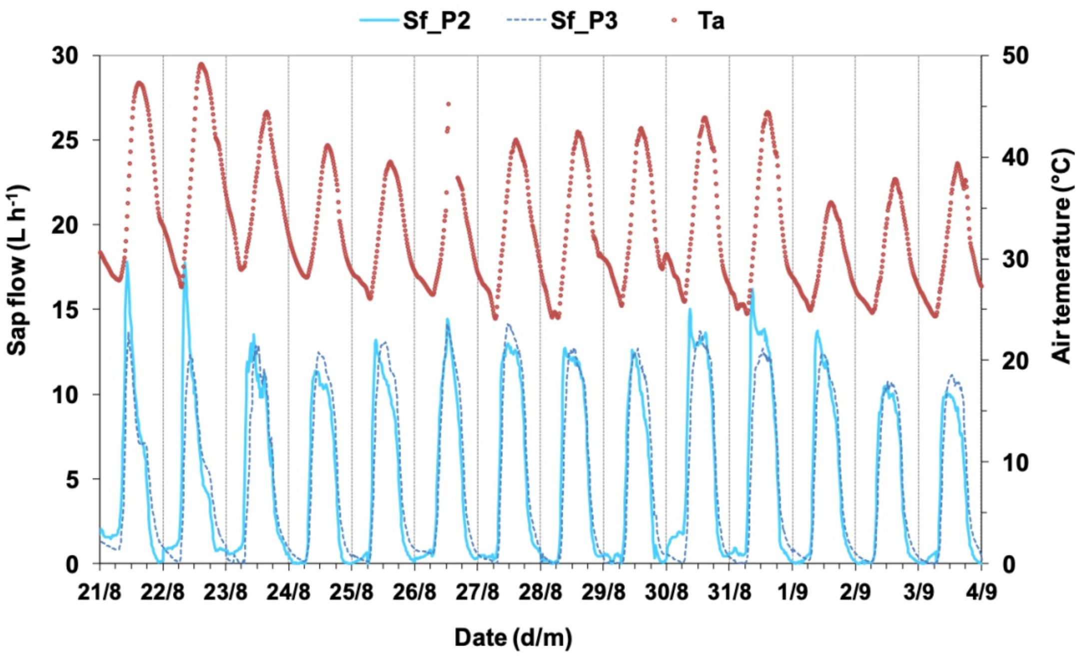


Figure 1. Daily courses of two neighboring palm trees (P2 and P3) sap flow (Sf) of and of the under-canopy air temperature (Ta): a series of 14 days measurement during summer season (233 to 246 DOY)

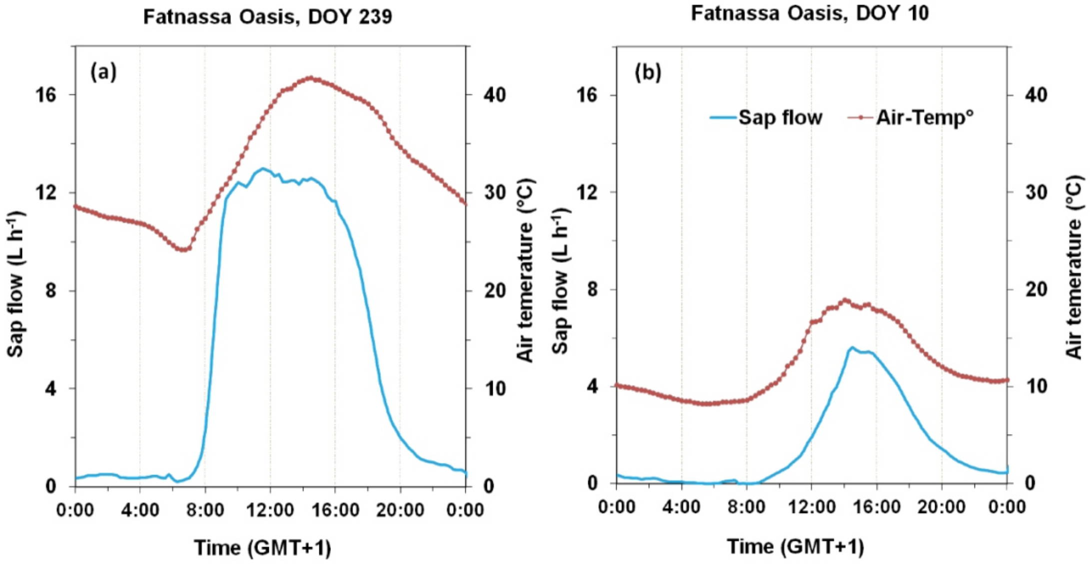


Figure 2. Daily courses of the date palm sap flow (L h^{-1}) and of the under-canopy measured air temperature (°C): A comparison between two evaporative demand contrasted sunny days; **(a)** DOY 239: Summer day with high evaporative demand, **(b)** DOY 10: Winter day with low evaporative demand

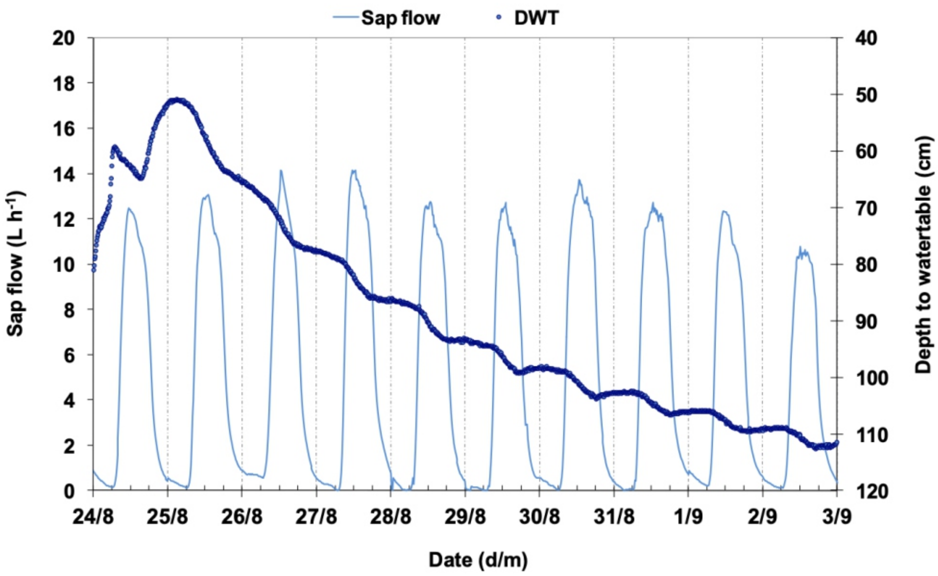


Figure 3. Temporal variation (236 to 245 DOY) of the date palm sap flow and of the depth to the shallow water table from the land surface (DWT) monitored inside the experiment field (10 min step values); (The irrigation event has occurred within DOY 235 and 236).

To demonstrate this relation between evapotranspiration outflow and the groundwater day-night oscillation, we superimposed the water table level and the instantaneous date-palm sap-flow courses. By curves observation, it can be seen clearly the synchronized evolving of the two phenomena. Indeed, after a nocturnal water table slow or zero drawdown phase, during which transpiration (sap flow) is almost zero, begin a more accelerated drawdown phase concomitant to the diurnal transpiration activity rise. It can be deduced here that the diurnal water table drawdown acceleration is, at least partially, driven by the date palm transpiration outflow. Similar results were found and discussed by Loheide II et al (2005) for some desert shrubs.

The concomitance of the drawdown acceleration course and the sap flow diurnal rise confers moreover, at least qualitatively, a more methodological strength to the date-palm transpiration assessment by sap flow measurement. The shallow water table nycthemeral fluctuation signal could therefore be valued to investigate the evapotranspiration flow of the total above-ground canopy inside the oasis scheme and to know more about the shallow groundwater contribution to this flow feeding.

Moreover, the hypothesis that date-palm behaves as a phreatophyte and can extract his water needs from the shallow groundwater seems to be demonstrated by this phenomena concomitance. In the literature, some authors mentioned that, being a tree of the desert, date palm requires sufficient soil moisture in their rooting zone (1.2 to 2 m depth) which is totally provided by a shallow (but non salty) water table or partially by regular adequate irrigation (Nixon, 1951; Munier, 1973, Liebenberg and Zaid, 2002; Chao and Krueger, 2007; El-Khoumsi et al., 2017).

Transpiration variation at daily time scale and with the irrigation frequency

Like at the hourly time-scale, sap flow averages show a high variability. Indeed, daily cumulated sap flow varied overall from 25 to 175 L d^{-1} $tree^{-1}$. Converted to mm d^{-1} unit (on the basis of planting density), daily transpiration varied thereby from 0.5 to 3.5 mm d^{-1} with an average of about 2 mm d^{-1} calculated over on the entire measurement period (between July and May of the following year). During monitoring summer season, (July-September), the daily palm transpiration averages ranged from 75 to 160 L d^{-1} $tree^{-1}$ which equivalent to 1.5 to 3.2 mm d^{-1} (Figure 4). During this critical water-need period, we received three monthly irrigation events of about 150±10 mm depth for each one. These three water deliveries are clearly differentiated through the consequent water table level raising (Figure 4).

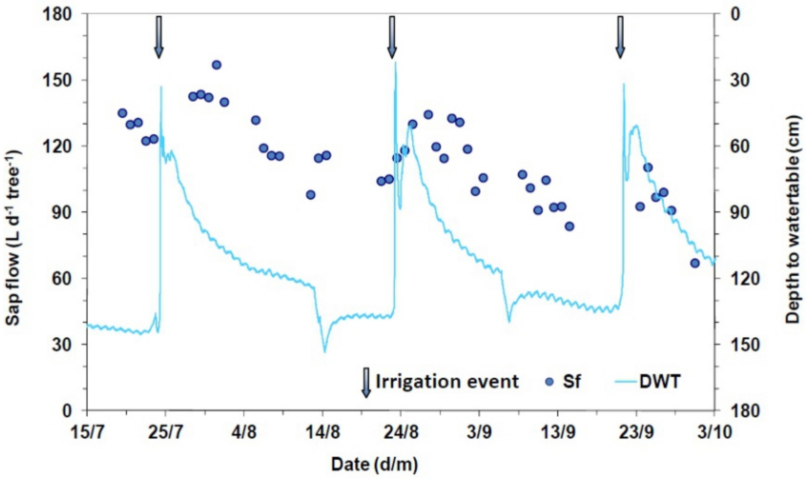


Figure 4. Temporal variation of the daily cumulated date-palm sap flow (L d^{-1} $tree^{-1}$) in relation to the irrigation events and the shallow groundwater depth (from DOY 196 to DOY 276).

It remains, however, an accurate evaluation of the low layer (forage crops and bare soil) contribution into the overall evapotranspiration. At the scheme scale it was deduced from salt and ionic balance (input-output) a yearly overall evapotranspiration of almost 1100 to 1200 mm yr^{-1} during a normal water supply functioning year (Marlet et al., 2007).

Noticed sources of error that may affect the date-palm sap flow measurement accuracy

In addition to the difficulty to localize the zero sap flow state and the derived ΔT_{max} determination inaccuracy described above, we distinguished, from the permanently unheated sensor signals or even from the other sensors when the power supplying battery is running out, a non-zero and repetitive temperature difference (ΔT) between the higher and lower sensor needles. The hypothesis of an equal temperature at the two needles insertion points under "without-heating" condition has a priori not been validated under field conditions (Cabibel et al., 1991a; Lu et al., 2004; Hölttä et al., 2015).

The temperature difference (Figure 6) is sharply negative (-0.2 to -0.6 °C) at the beginning of the day (between 7am and 11am, depending on the season) and gradually reversed the rest of the day to almost +0.3 °C with a daily and seasonal variation. This signal, common to all sensors under without-heating state, is then a not hazardous phenomenon, especially since it is repetitive with an observed effect of the daily solar and thermal cycle.

By superimposing the calculated flux density kinetics and the without-heating signal drawing(Figure 7), it has been noted that this offset can influence instantly flux density values, in particular by an early morning maximum appearance. Therefore, if we don't take this ΔT offset into account, we can be misled to explain this maximum by a greater morning transpiration activity. Consequently, we can even lose accuracy on the flux density calculation since the daily recorded amplitudes between maximum and minimum ΔT_{ϕ} were rather small (about 2.5 to 3 °C). This offset shouldn't be neglected since it can also induce an overestimation of ΔT_{max} whose consequences on the flux values can be significant (Peters et al., 2018).

The non-zero ΔT offset, recorded under without-heating condition, appears to have a significant effect on actual sap flow values which seem generally overestimated at the morning beginning (usually from sunrise to four hours later) and then underestimated towards the afternoon (Figure 7). However, this offset seems to have a less significant effect on the 24-hours cumulative flux since the afternoon underestimation will be compensated, ever partially, by the morning overestimation. The use of this without-heating ΔT offset to correct the under-heating sensor signal was tried to improve results accuracy (Figure 7). The corrected signal seem to be more coherent even concerning the daily evolving. However, since the unheated sensor was mounted on a distinct palm tree, we think that using its signal to correct the other trees' sensors signals is not much accurate.

Despite the thermal insulation precautions being taken during the installation, the observed non-zero ΔT offset, appears to be generated by thermal interferences related to external environment in particular to an air-soil temperature gradient which is rather variable during the day (Cabibel et al., 1991a ; Do and Rocheteau, 2002a). A better protection of the trunk base by shading-nets was attempted to attenuate the observed artifact peaks (Shackel et al., 1992; Roupsard et al., 2006). Regardless of the artifact origin, a signal correction and a measurement improvement should be implemented for a better measurement accuracy. There were some methodological attempts to skirt these temperature gradients by implementing cyclic heating (Do and Rocheteau, 2002b) or by appending in-opposition a cold sensor on the same trunk (Lu et al., 2004). A deeper investigation and research need to be performed to apprehend the artifact origin and to therefore suggest the reliable correction.

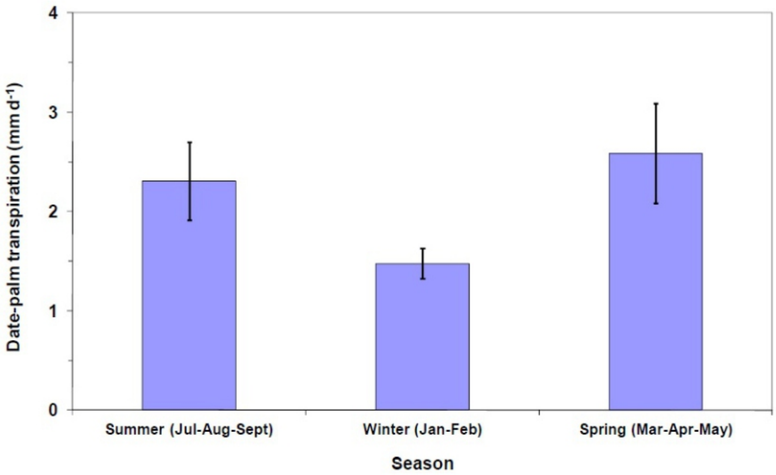


Figure 5. Seasonal means of the daily date palm transpiration (mm d^{-1}) inside the experiment field. Y bars represent ±Standard deviation

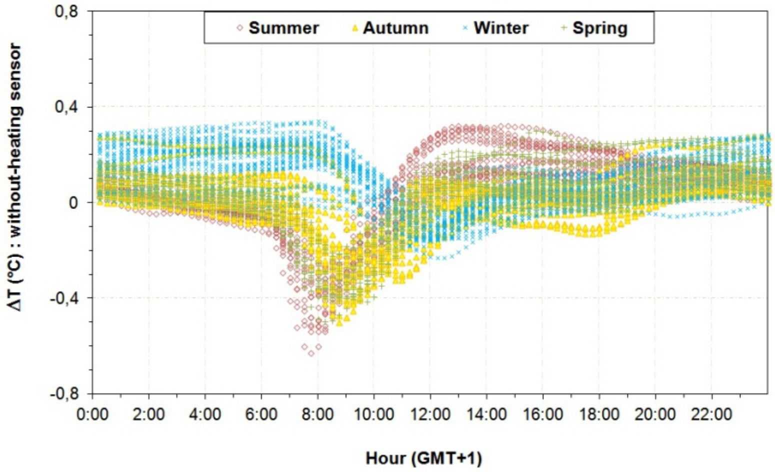


Figure 6. Seasonal variation of the ΔT signals recorded under without-heating state: highlighting of the non-zero thermal offset between the upper and lower needles of sap flow sensor. 15 days of the middle of each season are presented on this figure

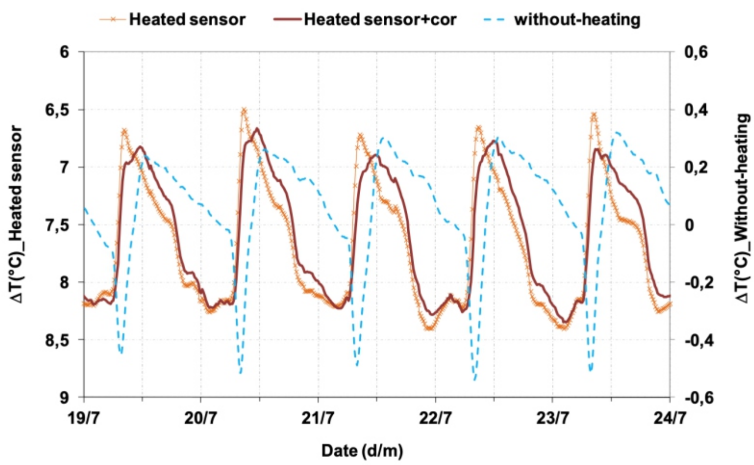


Figure 7. Comparison of the ΔT signals recorded under heating and without-heating state during five summer days: Approach to correct a heated sensor signal using a concomitant without-heating signal

Conclusion

This experiment tried to assess the date palm transpiration using the sapflow measurement and to investigate its hourly, daily and seasonal variation over one-year in relation to the main study site conditions (high evaporative demand, saline shallow water table, distant water supply deliveries)..

At the end of this work, the issued results showed that the instantly transpiration varied with the measured air temperature and was high-related to the monitored shallow water table nycthemeral fluctuation. The latter could therefore be valued to investigate the evapotranspiration flow of the total above-ground canopy and to know more about the shallow groundwater contribution to this flow feeding.

The daily transpiration rate, one-year-averaged at ~2 mm d^{-1}, ranged between 0.5 and 3.5 mm d^{-1} with a clear seasonal variation. Seasonal transpiration measured by this experiment ranged between 1.5 (winter season) and 2.6 mm d^{-1} (spring and summer seasons). During the summer hot season, a suspected-water-stress appearance according to water delivery frequency was also revealed. Indeed, the transpiration rate declined in few days after the irrigation events and could indicate a stress status related also to a detrimental salinity at the tree rhizosphere vicinity.

The one-year-cumulated transpiration was about 730 mm and represented almost 60% of the 1200 mm deduced-evapotranspiration for the overall oasis. From this experiment case, it was noted that the yearly date palm tree transpiration reflects a rather modest water consumption (35 to 45%) relatively to the surrounding Saharan high evaporative demand ranging between 1650 and 2000 mm yr^{-1}. It can therefore be deduced that the date palm tree, in itself, isn't a great water consumer in such cropping conditions. After more results validation, these quantitative elucidations should be considered to rethink the date palm irrigation scheduling and the water management practices inside oasis schemes.

Moreover, this work has revealed the existence of some uncertainties sources that can influence the sap flow measurements. All these issues should be considered in the future for a methodological improvement and more accurate results.

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Pest and beneficial insect species detected on broad bean in the Çukurova region of Turkey

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Abstract

Broad bean plants have an important status in human nutrition because they are rich in protein. In this study, harmful and beneficial insect fauna on pods of broad bean were studied in a limited area. The study was carried out in the commercial broad bean production areas in Çukurova region of Turkey between the years 2014-2016. In each survey, 4-8 fields were visited to determine the numbers of pest and predatory insect species. The size of commercial fields sampled varied from 0.5 to 1.0 ha. Sampling was carried out when plants were in the flowering-pod formation stage. Insect species were sampled by beating the plants vigorously into a white plastic container. A total of 14 harmful insects from 4 genera were identified. Western flower thrips, *Frankliniella occidentalis* (Pergande) dominated the pest insect fauna (a total of 444 individuals) accounting 40.07% of the total number of adults. Relatively high numbers of thrips and aphids were determined. A total of 9 predatory insect species from 2 genera were recorded. The most common predatory bug was *Orius niger* (Wollf) accounting for 76.83% of total adults collected. *Orius niger* was often detected with thrips species on flowers of plants. No damage due to insect pest species detected was observed throughout the sampling periods. This study suggests that growing faba bean in the winter-spring period, especially in agricultural areas having poor plant diversity in the Mediterranean region, could be useful for conservation and augmentation of beneficial insects.

Keywords: Pest, Beneficial, Insect, Broad bean

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Introduction

Broad bean is grown in almost all parts of Turkey; however, it is principally cultivated in the Mediterranean and Aegean regions such as Antalya, Aydın and Mersin provinces in Turkey. In 2017, fresh bean production was 37 511 tons and the area planted was 3.953,7 ha in Turkey (Anonymous, 2017). Faba bean production is fourth among the leguminous crops grown in Turkey.

There are various harmful and useful insects on the broad bean, which is important in human nutrition and also useful in soil nitrogen fixation. Harmful and beneficial insects on broad bean in Turkey have been studied in a limited area and often in experimental plots. (Atakan, 2010, 2012 and 2016)

In Turkey, the insect species and their pest status on faba bean in commercial fields have been studied. In previous studies performed in the same ecological area, insect pests of broad bean and their economic importance were described by Atakan and Ulusoy (2008) and the seasonal abundance of the western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) and the generalist predator *Oriusniger* (Wollf) (Hemiptera: Anthocoridae) were studied by Atakan (2010). Pest status of insects of faba bean in the Mediterranean countries including Tunisia, Syria was documented by Weigand and Bishara (1991). According to Weigand and Bishara (1991), aphids and *Sitona* spp. were the main pests of faba beans in those countries. Nuessly et al. (2004) reported 61 herbivorous insect pest species and 32 predator and parasitoid species on faba bean in Florida (USA); and *Aphis craccivora* Koch (Hemiptera: Aphididae) was the most damaging pest of faba bean in their study. Although some associations between pest thrips and generalist predators on faba bean flowers have been studied in the restricted area of Balcalı (Adana province, Turkey), the fauna of thrips and beneficial insects and the their pest status on broad bean in commercial fields of faba bean in the Çukurova Region of Turkey are not well understood. During the winter and early spring months, the flowering broad bean can have ecological effects in the protection of beneficial insects, providing shelter and ovipositon area, nectars and pollens sources. In commercial bean production areas, harmful and beneficial insect fauna and their densities due to pesticide applications may vary.

The aim of this study was to investigate the fauna of harmful and beneficial insects on broad bean in commercial farms in Çukurova region of Turkey. In addition, observing the damage status of harmful insects may contribute to studies of integrated pest control in broad bean fields in the region.

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Material and Methods

The study was carried out in the commercial broad bean production areas in Çukurova region of Turkey between the years 2014-2016. Abundance of pest and beneficial insect species were investigated in commercial faba bean fields during the 2014-2016 growing seasons in Adana Province, Turkey. Surveys were carried out once a month during the growing season. During surveys, the same fields were regularly sampled. In each survey, 4-8 fields were visited to determine the numbers of thrips and predatory insects. The size of the commercial fields sampled varied from 0.5 to 1.0 ha. Sampling was carried out when plants were in the flowering-pod stage. Each field was divided into four quarters (1.250-2.500 m^2 sub-plots) as replicates. Five plants in each sub-plot were randomly selected. Insect species were sampled by beating the plants vigorously into a white plastic container (37 × 28 × 7 cm) for about 5 sec. Collected insect species were counted by using a hand lens in the field. Most *Orius* specimens were released to the plots and a few were taken to the laboratory for identification. Insects that could not be identified in the field were transported to the laboratory and some of them were killed with the help of a killing jar. Small and soft-bodied insects were kept in 60% ethanol. In the laboratory, the thrips samples were transferred into vials containing AGA solution (i.e. 10 parts 60% ethanol, one part glacial acetic acid, and one part glycerin) and kept for one day. Thrips species were slide-mounted and identified under a binocular microscope.

Thrips (adults) were identified by using the keys given by zur Strassen (2003) and Balou et al. (2012). *Orius* spp. were identified with the keys given by Önder (1982) and Tommasini (2004). Other isolated predators and pestiferous insect species were identified by reference to materials stored in the Entomology Laboratory of the Department of Plant Protection, Faculty of Agriculture, University of Çukurova, Adana, Turkey. No identification keys are available for nymphs of *Orius*. Therefore, these were treated as a single group.

Results

Total numbers of insect pest species on broad bean

The total numbers of insect pest species collected from broad bean plants are given in Table 1. The highest number of aphids, *Aphis fabae* Scop. (Hemiptera: Aphididae) (101 individuals) was detected on 26 March 2015.

A relatively higher number of this aphid was recorded on 14 April 2015. The number of *Acyrthosiphon pisum* (Haris) (Hemiptera: Aphididae) was the highest on 14 April 2015. On the other sampling dates, few numbers of aphid species were encountered. Only three individuals of *Epicometis hirta* Poda (Coleoptera: Scarabaeidae) were recorded on flowers on 26 March 2015.

Leafhopper, *Empoasca decipiens* Paoli (Hemiptera: Cicadellidae) was regularly sampled throughout the study. The numbers were relatively higher on plants leaves on 6 February 2015 (54 individuals), on 26 March2015 (109 individuals) and on 14 April 2015 (49 individuals). Similar to the leafhoppers, individuals of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) were recorded on flowers throughout the growing season. The highest density on broad bean flowers was recorded on 8 December 2015 (103 individuals). Excluding 16 December 2014, 14 April 2015, and 11 November 2015, the numbers of these pest thrips were similar, ranging 55-74 individuals on flowers. *Meligethes* sp. (Coleoptera: Nitidulidae) were observed on flowers of plants on 6 February 2015 (16 individuals) and 26 March 2015 (8 individuals). Total densities of this pest declined to zero level on other sampling dates. A few numbers of curculionid, *Sitona* sp. (Coleoptera: Curculionidae) were detected on flowers on 6 February 2015 and 26 March 2015. A relatively high number of *Thrips hawaiiensis* (Morgan) (Thysanoptera: Thripidae) (20 individuals), which is a serious pest of citrus lemon in Mersin province, Turkey, was extracted from flowers of broad bean plants on 8 December 2015. On other sampling dates, there was no thrips species or their numbers were very low.

Total numbers of predatory insect species on broad beans according to sampling dates are shown in Table 2. Predatory thrips, *Aeolothrips collaris* Priesner (Thysanoptera: Aeolothripidae) were detected on only one sampling date (1 individual). Predatory mirid, *Campylomma nicolasi* Puton and Reuter (Hemiptera: Miridae) was not found on some sampling dates, its density ranged between 2 and 13 individuals. Very few numbers of coccinellid predators [*Coccinella semptempunctata* L. and *Hippodamia variegate* (Goeze)] (Coleoptera: Coccinellidae) were recorded throughout the sampling dates. Predatory anthocorid, *Orius laevigatus* were found scarcely on flowers when compared to another predatory bug *Orius niger* (Wollf) (Hemiptera: Anthocoridae). *Orius niger* was the most common predatory bug in surveyed commercial fields in this study. Total density of this beneficial insect was highest (77 individuals) on 26 March 2015. Its numbers were very few at the nonflowering stage of sampled plants i.e. in November.

In this current study, 14 pest insect species in 4 genera were identified. In previous studies done in Balcalı district, Adana province, Turkey, 17 harmful insect species and one genus were determined (Atakan and Ulusoy 2008). Harmful insect species and their densities found in those previous studies were higher than were found in the current study. This is probably due to intense insecticides applications in commercial fields in the region. However, in those previous studies, no insect damage on broad bean plants was detected. Additionally, no insect damage was also observed on plants grown in the surveyed commercial fields. This study suggests that insecticide applications performed against pest insects such as aphids and leafhoppers in the region are not needed. A total of 9 predatory beneficial insect species in 2 genera were also identified. Captured predatory insect species numbers and diversity were similar to previous studies done in Balcalı location which is a polyculture area (Atakan and Ulusoy, 2008; Atakan and Malik, 2018).

Proportions of pest and predatory insect species on broad bean

Seasonal numbers and proportions of pest insect species identified in the surveyed fields are given Table 3. *Frankliniella occidentalis* dominated the pest insect fauna (total number was 444 individuals) accounting for 40.07% of the total number of adults. *Empoasca decipiens* was the second most common insect species, comprising 21.49% of the total individuals. *Aphis fabae* and *Acyrthosiphon pisum* had similar proportions in total number (11.60% and 18.43%, respectively).

Proportions of other pest insect species collected from plants were less than 3%. *Frankliniella occidentalis* was found to be the dominant pest thrips in the current study. This may be due to its wide host range, high reproductive rate, wide geographic distribution and better adaptation to hard winter conditions (Kirk and Terry, 2003). This pest thrips is commonly found on many host plants (Atakan 2008a, b) and wild plants (Atakan and Uygur 2005; Atakan and Tunç, 2010) in the Çukurova region.

Seasonal numbers and proportions of beneficial insect species identified in the surveyed fields are given in Table 4. A total of 9 predatory insect species in 2 genera were identified during this study. *Orius niger* dominated the predatory insect fauna, accounting for 76.83% of total adults.

Table 1. Total numbers of pest insect species on broad bean according to sampling dates in Çukurova Region of Turkey during 2014-2016.

Insect species	28 Nov., 2014	16. Dec., 2014	6. Feb., 2015	26.Mar., 2015	14. Apr., 2015	11. Nov., 2015	8. Dec., 2015	20.Jan., 2016	23 Feb., 2016
Meligetes sp.	0	0	16	8	0	0	0	0	0
Sitona sp.	0	0	9	3	0	0	0	0	0
Aphis fabae	0	0	10	101	16	0	0	2	0
Acyrthosiphon pisum	0	3	0	43	158	0	0	1	0
Epicometis hirta	0	0	0	3	0	0	0	0	0
Empoaca decipiens	0	1	54	109	49	2	6	5	13
Dolycoris baccarum	0	0	0	0	1	0	0	0	1
Lygus sp.	0	0	0	0	0	1	0	0	0
Oxycarenus hyalinipennis	0	0	0	0	0	1	0	0	1
Frankliniella occidentalis	65	23	51	74	8	9	103	56	55
Isoneurothrips australis	0	1	0	0	0	0	0	0	0
Kakothrips priesneri	1	0	0	0	0	0	0	0	0
Melanthrips pallidior	0	0	0	2	0	0	1	0	0
Thrips hawaiiensis	0	0	0	0	0	1	20	0	0
Thrips major	0	0	0	0	0	0	0	0	1
Thrips meridionalis	0	0	0	0	0	0	0	0	2
Thrips tabaci	0	0	2	2	2	0	0	0	0
Total	66	17	142	345	234	14	130	64	73

Table 2. Total numbers of beneficial insect species on broad bean according to sampling dates in Çukurova Region of Turkey during 2014-2016.

Insect species	28 Nov., 2014	16. Dec., 2014	6. Feb., 2015	26 Mar., 2015	14. Apr., 2015	11. Nov., 2015	8. Dec., 2015	20 Jan., 2016	23 Feb., 2016
Coccinella septempunctata	0	0	2	0	0	0	0	0	0
Hippodamia variegata	0	0	0	0	0	0	0	0	1
Campylomma nicolosi	10	4	3	0	0	13	3	0	2
Orius majusculus	0	1	1	0	0	0	2	1	0
Orius laevigatus	0	9	3	0	0	1	1	3	1
Orius niger	7	58	33	77	8	7	22	19	12
Piocoris erythrocephalus	0	0	0	0	0	1	0	0	0
Chrysoperla carnea	0	0	0	0	0	0	0	4	1
Paederus sp.	1	0	0	0	0	0	1	0	0
Tachyphorus sp.	2	0	0	0	0	0	0	0	1
Aeolothrips collaris	0	0	0	1	0	0	0	0	0
Total	20	72	42	78	8	22	29	27	18

Table 3. Proportions of pest insect species on broad bean in Çukurova Region of Turkey during 2014-2016.

Order/Family	Total no of pest insects	The proportion in total number (%)
Coleoptera/Curculionidae)		
Sitona sp.	12	1.07
Coleoptera/Nitulidae		
Meligethes sp.	24	2.15
Coleoptera/Scrabaeidae		
Epicometis hirta Poda	3	0.26
Hemiptera/Aphididae		
Aphis fabae Scop.	129	11.60
Acyrthosiphon pisum (Haris)	205	18.43
Hemiptera/Cicadellidae		
Empoasca decipiens Paoli	239	21.49
Hemiptera/Lygaeidae		
Nysius sp.	15	1.34
Oxycarenus hyalinipennis Costa	2	0.17
Hemiptera/Miridae		
Lygus sp.	1	0.08
Hemiptera/Pentatomidae		
Dolycoris baccarum (L.)	1	0.08
Thysanoptera/Aeolothripidae		
Melanthrips pallidior Priesner	3	0.26
Thysanoptera/Thripidae		
Frankliniella occidentalis (Pergande)	444	40.07
Isoneurothrips australis Bagnall	1	0.08
Thrips hawaiiensis (Morgan)	22	1.97
Thrips major (Priesner)	1	0.08
Thrips tabaci Lindeman	7	0.62
Kakothrips robustus (Uzel)	1	0.08
Thrips meridionalis Uzel	2	0.17
Total	1112	100

Table 4. Proportions of beneficial insect species on broad bean in Çukurova Region of Turkey during 2014-2016.

Order/Family	Total no of beneficial insects	The proportion in total number (%)
Coleoptera/Staphylinidae		
Paederus sp.	2	0.63
Tachyphorus sp.	3	0.94
Coleoptera/Coccinellidae		
Coccinella septempunctata	2	0.63
Hippodamia variegate Goeze	1	0.31
Hemiptera/Anthocoridae		
Orius laevigatus (Fieber)	18	5.69
Orius majusculus (Reuter)	5	1.58
Orius niger (Wollf)	243	76.89
Hemiptera/Lygaeidae/Geocorinae		
Piocoris erythrocephalus (Lepeletier and Serville)	1	0.31
Hemiptera/Miridae		
Campylomma nicolosi Puton and Reuter	35	11.19
Neuroptera/Chrysopidae		
Chrysoperla carnea (Stephens)	5	1.58
Thysanoptera/Aeolothripidae		
Aeolothrips collaris Priesner	1	0.31
Total	316	100

Orius niger was followed by *C. nicolasi* with a proportion of %11.19. The proportion of *Orius laevigatus* was 5.63%. Proportions of other predatory insects were less than 2%. *Orius niger* was the most notable predatory bug. The results agree with findings of Tommasini (2004), who found that *O. niger, O. laevigatus*, and *Orius majusculus* (Reuter) were common anthocorid species in the Mediterranean basin. *Orius niger* was dominant in northwestern Italy, whereas *O. laevigatus* was more common in the warmest locations of the country (Bosco et al., 2008). Thus, the predominance of insect species may depend on location.

Orius and thrips species identified in this study visited mostly flowers during the flowering periods of plants in commercial fields. High numbers of both insects inhabited the flowers in previous studies done in the Balcalı location (Atakan and Malik, 2018). In addition, there was a positive and significant relationship between numbers of thrips and numbers of *O. niger* found on the flowers (Atakan and Malik, 2018). According to the findings of some studies, *Orius*

1962; Salas –Aquilar and Ehler, 1977; Kiman and Yeragan, 1985). Nuessly (2004) also indicated that considerable numbers of beneficial insect species colonized the faba bean grown in southern Florida (USA). The broad and closed flower structure of broad bean may have created favorable conditions in protecting beneficial insects from hard winter conditions and predations.

Seasonal numbers of some predatory insects related to some pest insects

Seasonal numbers of some predatory insects identified with some pest insects on broad bean are given in Table 5. Most *O. niger* were detected together with *F. occidentalis* and *E. decipiens*. Relatively higher densities of *O. laevigatus* were also found in association with *F. occidentalis*. A relatively higher number of *C. nicolosi* was found in association with *F. occidentalis*. The numbers of predatory insects found together with other pest insects were low.

Table 5. Seasonal numbers of some predatory insects identified with some pest insects on broad bean in Çukurova region of Turkey during 2014-2016.

Pest insects	Predatory insects		
	Campylomma nicolosi	*Orius laevigatus*	*Orius niger*
Acyrthosiphon pisum	1	3	23
Aphis fabae	2	0	51
Frankliniella occidentalis	22	15	135
Empoasca decipiens	5	8	80
Meligethes sp.	2	3	30
Nysius sp.	0	2	5
Sitona sp.	2	1	25

Table 6. Prey/predator ratios on broad bean in Çukurova region of Turkey during 2014-2016.

Sampling dates	Prey (thrips) /predator (*Orius*)	Prey (leafhopper)/predator (*Orius*)
28 Nov., 2014	9.28	-
16 Dec., 2014	0.39	0.01
6 Feb., 2015	1.54	1.63
26 Mar., 2015	0.96	1.41
14 Apr., 2015	1.0	6.12
11 Nov., 2015	1.28	0.28
8 Dec., 2015	4.68	0.27
20 Jan., 2016	2.94	0.26
23 Feb., 2016	4.58	1.08

Prey/predator ratios

Monthly prey (thrips or leafhopper (*Empoasca*)/predator (*Orius* spp.) ratios are presented in Table 6. Prey (thrips)/predator (*Orius*) ratios were less than 10 thrips per *Orius*. The highest prey predator ratio was detected on 16 December 2014 as 9.28 thrips per *Orius*. Prey/predator ratios were lower (less than 5 thrips per *Orius*) when compared to the previous sampling date. Prey (leafhoppers)/ predator (*Orius*) ratios on the sampling dates were less than 7 leafhoppers per *Orius*. The ratio was relatively greater on 14 April 2015 as 6.12 leafhoppers per *Orius* when compared the ratios found on other sampling dates. Leafhopper/*Orius* ratios were less than 2 leafhoppers per *Orius* on the most sampling dates.

Frankliniella occidentalis was under the predation risk in the flowers due to *Orius* attacks. There was clear suppression of *F. occidentalis* populations by *Orius* on the broad bean. Prey-predator ratios on most sampling dates were very lower (less than 10 thrips per *Orius*) than previously reported ratio, 217 thrips per *Orius,* which is critical for *Orius insidiosus* to sufficiently suppress the population of *F. occidentalis* in greenhouses (Sabelis and van Rijn, 1997). Effective suppression of the thrips by a predator depends on several factors including initial population densities of the prey and predator, their fecundity and structure of the host plants (Osekre et al., 2008). The leafhoppers/*Orius* ratios were low on most sampling dates; however, this may not indicate efficient predation of the leafhoppers by the *Orius* species since pest leafhoppers feed mostly on foliage and *Orius* species visit mostly flowers. In light of this, leafhoppers may have a lower predation risk due to generalist predators, such as *Orius* species.

Conclusions

As a result, broad bean is rich in beneficial and harmful insect fauna even though they were captured in fewer numbers in the commercial fields. Majority of the identified pests on broad bean are polyphagous pests and were already recorded in Adana (Atakan and Ulusoy, 2008). According to previous study done in same area (Atakan, 2010) no pest insect damages were observed even in the non-insecticide treated plots of the broad beans. This result is in agreement with the findings of current study. Therefore insecticide applications are not recommended, this is especially important for the protection of natural enemies including predators. Broad bean is especially more attractive to generalist predatory bugs, *Orius* species (mainly *O. niger*). For this reason, the cultivation of the broad bean in mono-cultural agricultural systems can increase efficiency of these predatory taxa through providing overwintering, feeding, mating sites, and thus their reproduction. Beneficial insects may have an important role in suppressing pest insects on summer crops in the region. For this purpose, the insect biodiversity may be increased with the faunistical studies on broad bean in different ecological regions of Turkey, and the importance of these beneficial species can be converted to a useful position in terms of pest management on subsequent arable crops.

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Agro-economic performance of boro rice cultivation at farmers' level of *haor* area in Bangladesh

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Abstract

The present study is an attempt to see the boro rice cultivation and agro-economic performance in *haor* area. A total number of 65 farmers' were randomly selected by using random sampling technique. Data were collected from the sampled farmers' through direct interview method using a questionnaire. The study was carried out to list down the available 31 boro rice variety cultivated in the *haor* area. Most of the farmers had low capital consuming agricultural machinery. Considering all farmers, per hectare labourer required for boro rice cultivation in *haor* area was 149 man day^{-1} ha^{-1}. The highest per hectare labourer required for boro rice cultivation in *haor* area was found 157 man day^{-1} ha^{-1} in case of medium farmers followed by large (154 man day^{-1} ha^{-1}), small (149 man day^{-1} ha^{-1}), marginal (147 man day^{-1} ha^{-1}) and landless (138 man day^{-1} ha^{-1}) farmers, respectively. Considering full cost, the average cost of rice production was Tk. 38153 ha^{-1} under the all sampled farmers'. Farmers' average cost of rice production for land preparation, intercultural operation, seed, fertilizer, irrigation, pesticide, harvesting, threshing, carrying and others were of Tk. 3735, 6882, 1913, 6309, 2523, 782, 9277, 3421, 3074 and 237 ha^{-1}, respectively. The average all sampled farmers' net-return earned form boro rice production was Tk. 52646 ha^{-1} and yield was 5.31 t ha^{-1}. The economic returns earned from rice production of Tk. 49137, 52595, 50777, 56338 and 55003 ha^{-1} against the yield of 4.97, 5.26, 5.24, 5.60 and 5.45 t ha^{-1} for landless, marginal, small, medium and large farmers' categories, respectively. Productivity of boro rice is low due to imbalance use of fertilizers but yield showed higher than that of national average production in Bangladesh due to one cropped area in *haor*.

Keywords: Agro-economic, Variety, Farmers' level, Yield, Haor

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Introduction

Bangladesh is densely populated and agriculture based country. Total rice growing area was 11.38 million ha in Bangladesh which covers 74.85% of the total cultivable area and the total production of rice was 34.71 million metric tonnes (BBS, 2016). Agriculture is the single largest producing sector of economy since it comprises about 14.1% of the country's GDP and employing around 62.1% of the total labor force (BBS, 2017). There are as many as 373 small or large *haors* in Bangladesh (Master Plan of *Haor* Area, 2012). There are many *haors* (basin like structure) where water remains either stagnant or in flash flooding condition during the months of May to October and mainly Boro rice is grown in the Rabi season using irrigation. Geographically, most of the *haors* are situated in seven districts of the North-East Bangladesh. The districts are Sunamganj, Kishoreganj, Netrokona, Sylhet, Habiganj, Maulavibazar and B. Baria. The Hakaloki *haor*, Sumir *haor*, *Dakar haor*, Tanguyar *haor*, Gungiajuri *haor*, Mukhar *haor*, Kaowadighir *haor* etc are the prominent *haors* in Bangladesh. The total cultivated area in those *haor* districts is about 1.26 million hectares of which 0.68 million ha (nearly 66%) is under *haor*. Almost 80% of this area (i.e. 0.68 million ha) is covered by Boro rice, while only about 10% area is covered by T. Aman production (Huda, 2004). Out of these, 95 *haors* are in Sunamganj district of which about 70% area has now been turned into cultivated land (Master Plan of Haor Area, 2012). Boro-Fallow-Fallow and Fallow-Fallow-T. Aman are the major cropping patterns practiced in the area. So, there is a great possibility of growing modern variety rice as well as other rice and non-rice crops in the *haor* areas. One of the major reasons for nutrient stress is the use of imbalance fertilizers. Among the improved cultural practices, to insure proper growth, large amount of chemical fertilizers are applied in different crops field (Shakouri *et al*., 2012). Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Alam *et al*., 2009). Farmers' of *haor* area do not apply balance doses of fertilizers because of higher yield of rice comparison to other areas of Bangladesh. It is most important that the actual fertilizer application should be known to manipulate the adequate fertilizer input supply for higher production and social appreciation to apply balance

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doses of fertilizers in their crops land. Human labour was the most important and extensively used input for producing boro rice. Production of boro rice required different operations such as land preparation, transplanting, weeding, fertilizer & insecticides application, irrigation, harvesting, carrying, threshing, winnowing and drying etc. So, boro rice is the main crop and even the only crop of those haor areas due to lengthy water logging condition. In those areas, rice cultivation is mainly dependent on the natural water although artificial irrigation is managed in some possible localities. The production of such areas is confined under the choice of the nature. Sometimes the ripen rice is damaged by the uncertain floodwater in the very low areas. Due to lengthy water logging those *haor* areas are mostly single cropped areas. The study was undertaken to see the boro rice varieties practiced in *haor* area with their production technology and agro-economic performance.

Materials and Methods

The study was carried out at Bahadurpur village under Sunamganj sadar upazila of Sunamganj district during November 2014 to July 2015 to examine the boro rice production in *haor* area. In Sunamganj Sadar upazila, the highest rainfall occurs in the months of end of May to mid-August while drought was prolong during end of November-mid February. Severe flood was reported in end of June to mid-August while warm weather persists at the end of end of March to mid-July. The list of all farmer in the selected village was prepared with the help of local village leader and SAAO. There were 230 households are situated in the Bahadurpur village. Sample farmers were selected following simple random sampling method. The numbers of sample farmers were 65. A semi-structured questionnaire was used as the data gathering instrument based on the objectives of the study. The questionnaire contained both open and closed form of questions. The questions in the schedule were simple, direct and easily understandable by farmers. Prior to final data collection, the questionnaire was pre-tested in the study area in the actual field situation. Based on their reactions the questionnaire was then finalized and multiplied to collect data. All possible efforts were made to explain the purpose of the study to the farmers' in order to get valid and pertinent information from them. While starting interview with a farmer, the researcher took all possible care to establish rapport with him so that he did not feel hesitant or hostile to provide responses to the questions and statement in the questionnaire. In some cases the investigator failed to meet the farmers' at their homes for interviews. However, this problem was resolved by repeating the visit. Only a single questionnaire was carried out with each farmer. The data collections were based on the rice varieties, labourer used in rice production, cost of rice cultivation and rice yield and economic returns. The collected data were compiled, tabulated, farmers categories, means and percentage according to objectives of the study.

Results and Discussion

Boro rice varieties cultivation in *haor* area

Haor is deeply flooded from May to October while winter is the single cropping season. The major crop is boro rice. In this study, boro rice is divided into three types such as local, modern and hybrid. Data found from the study, it was revealed that 17 local rice varieties, 13 modern rice varieties and 3 hydrid rice varieties were cultivated in *haor* area under Sunamjanj district, respectively (Table 1). The *haor* areas are naturally hazardous compared to those of the other irrigated areas of the country. A boro rice in the *haor* area generally encounters the difficulties like a failure of timely crop establishment, cold injury in the reproductive stage of an early crop, flash flood damage at the premature to mature stage of a crop etc. The normal seeding time in the seedbed is early November for a long-duration variety like BRRI dhan29 and mid to end-November for a short-duration variety like BRRI dhan28. The seedbed preparation depends on the time of receding of flood water in the *haor* area. Generally, the October seeded crop was to encounter cold shock at the reproductive phase from late February to early March. On the contrary, the late established (seedbed preparation in December) crop have the probability to encounter flash flood at the late growth stage of the crop. So the farmers have to play with the wheel of fortune for their survival in the area. Similar results were also observed by Singh (2008), Hossaio *et al.* (2006).

Table 1. Boro rice varieties cultivated at farmers' level in *haor* area

Variety type	Name of the variety		
Local	Rata boro	Birun	Rangilatapi
	Tapi boro	Laldinga	Kali boro
	Begun bichi	Khaia boro	Kalojira
	Atobshail	Bichibaroi	Lalkhai
	Gochi	Sona rata	Chinigura
	Laphaia	Pashushail	
Modern	BR 16	BRRI dhan50	Binadhan 10
	BR18	BRRI dhan58	Binadhan 14
	BRRI dhan28	BRRI dhan63	Binadhan 18
	BRRI dhan29	Binadhan 8	
Hybrid	Hybrid SL-8H	Hybrid Hira	BRRI hybrid dhan 2

Technology used of boro rice cultivation

Boro rice production is depending on different type technology. In this study that most of the farmers had low capital consuming agricultural machinery. But heavy capital consuming machinery was possessed only by the large farmers (Table 2). Animal power and power tiller was used for land preparation in boro rice cultivation. But the rate of using power tiller for land preparation was more than that of plough. The farmers were found to use fertilizers in their boro rice field namely Cowdung, Urea, TSP and MoP. It was observed from the study that 100% of the farmers used Urea in their rice field. Almost all farmers were used both mechanical and manual weeding to remove weeding in their rice field. Generally manual weeding was given to the very low land where minimum number of weeding was required. Irrigation is mainly dependent on the natural water although artificial irrigation is managed in some possible localities. Insecticides and weedicide were used by some farmers. Probably for this reason most of the farmers did not want to make any production loss due to insects in their farms. For threshing, most of the farmers used traditional hand beating and some thresher. The results are in close agreement with those of Abdullah *et al.* (2007), Hyun (2007), Zaman *et al.* (2007) Rosegrant and Pingali (2006) Myint and Kyi (2005).

Labourer of boro rice cultivation

The labour required for rice cultivation was 149 man day^{-1} ha^{-1} in average per farms. Farmers' had required labour of seedling uprooting, seedling transplanting, weeding, irrigation, fertilizer application, harvesting, threshing and carrying as of 10, 35.96, 27.53, 10.09, 3, 37.11, 13.68 and 12.29 man-day ha^{-1}, respectively (Table 3). Labourers for producing boro rice at farmers' level were transplanting (man-day 30.46, 33.96, 36.59, 39.79 and 38.97 ha^{-1}), weeding (man-day 24.70, 26.37, 27.10, 30.46 and 29.29 ha^{-1}), irrigation (man-day 9.22, 10.50, 9.51, 10.98 and 9.99 ha^{-1}), harvesting (36.56, 36.84, 37.69, 37.32 and 36.45 ha^{-1}), threshing (14.00, 14.20, 13.54, 13.17 and 13.50 ha^{-1}) and carrying (11.03, 12.14, 12.44, 12.90 and 12.94) in case of landless, marginal, small, medium and large farmers, respectively. Result shows that the highest number of labour was used for seedling, transplanting, weeding and harvesting. The result also supported by Chowdhury (2009), Mahabub *et al.* (2005), Khan (2004) and Miah (2002).

Table 2. Technology used of boro rice cultivation at farmers' level in *haor* area

Technology	Use
Power tiller Plough Yoke Ladder Rake Spade	Land preparation
Cowdung, Urea, TSP, MoP	Commonly used fertilizer
Dul Cheuti Water pump	Irrigation purpose
Insecticides	Insect control
Weedicide Japanese rice weedier	Weed control
Niri Spade Sickle Pearching Wood or bamboo Sticks Hand picking of harmful insects Removal diseased infected plants by hands	Intercultural operation
Sickle	Boro rice harvesting purpose
Dam Wood girth Threshing machine	Boro rice threshing purpose

Table 3. Labourer in boro rice cultivation of sampled farmers' land in *haor* area of Bahadurpur village under Sadar upazila of Sunamganj district
(Man-day ha^{-1})

Farmers category	Labour distribution in rice cultivation								Average
	Seedling uprooting	Transplantig	Weeding	Irrigation	Fertilizer application	Harvesting	Threshing	Carrying	
Landless (10)	10	30.46	24.70	9.22	3	36.56	14.00	11.03	138
Marginal (16)	10	33.96	26.37	10.50	3	36.84	14.20	12.14	147
Small (18)	10	36.59	27.10	9.51	3	37.69	13.54	12.44	149
Medium (15)	10	39.79	30.46	10.98	3	37.32	13.17	12.90	157
Large (6)	10	38.97	29.29	9.99	3	36.45	13.50	12.84	154
Total (65)	10	35.96	27.53	10.09	3	37.11	13.68	12.29	149

Figures within the parentheses indicate farmers' number

Cost of boro rice cultivation

The total farming operations costs per hectare of cultivable land in landless, marginal, small, medium and large categories of farmers were Tk. 35618, 37732, 38028, 40241 and 38659 respectively (Table 4). The average cost of rice cultivation was Tk. 38153 ha^{-1} in the study area. Farmers' average cost of rice cultivation for land preparation, intercultural operation, seed, fertilizer, irrigation, pesticide, harvesting, threshing, carrying and others were of Tk. 3735, 6882, 1913, 6309, 2523, 782, 9277, 3421, 3074 and 237 ha^{-1}, respectively. Intercultural operation was also shown that cost of boro rice per hectare varied from Tk. 6175 to 7322. The average seed, fertilizer, irrigation and pesticide highest costs per hectare land were Tk. 2121, 6529, 2744 and 1235 for medium categories of farmers respectively, and lowest costs per hectare land were 1540, 6014, 2305 and 371 in landless, respectively. From the study, harvesting cost per hectare area was highest than all other parameters. Finding showed that the cultivation of boro rice was of 9.68 t ha^{-1} in BARI dhan29 and 9.89 t ha^{-1} in BRRI dhan58. The gross return was of Tk. 116684 and 115598 for BARI dhan29 and BARI dhan58, respectively. It was observed that the balanced application of recommendation fertilizers gave the higher return as well as soils keep fertile (Al-amin, 2016). Khan (2004) observed that the costs of production of boro rice were Tk. 26814, 24914 and 24341 ha^{-1} for small, medium and large farms, respectively. In general labour, power tiller, seedlings, fertilizers, irrigation and insecticides emerged as the very crucial contributors to increase income from boro rice production. Similar results were also observed by Alam *et al.* (2011), Rahman (2000), Nantu (1998) and Bhuiyan (1986).

Table 4. Cost of boro rice cultivation for sampled farmers' land in *haor* area in Bahadurpur village under Sadar upazila of Sunamganj district (Tk. ha^{-1})

Farmers category	Cost of rice cultivation										Total cost
	Land preparation	Intercultural operation	Seed	Fertilizer	Irrigation	Pesticide	Harvesting	Threshing	Carrying	Miscell aneous	
Landless (10)	3735	6175	1540	6014	2305	371	9139	3499	2758	82	35618
Marginal (16)	3735	6592	1888	6246	2624	618	9211	3551	3036	232	37732
Small (18)	3735	6774	2028	6303	2379	686	9423	3385	3110	206	38028
Medium (15)	3735	7616	2121	6529	2744	1235	9331	3293	3225	412	40241
Large (6)	3735	7322	1737	6434	2497	1070	9112	3376	3211	165	38659
Total (65)	3735	6882	1913	6309	2523	782	9277	3421	3074	237	38153

Figures within the parentheses indicate farmers' number

Boro rice yield and economic returns

Return was calculated by multiplying the total production with market unit price (Tk kg^{-1}) of rice and straw. The average economic return form boro rice production was Tk. 52646 ha^{-1} and yield was 5.31 t ha^{-1} in the study area (Table 5). The economic return from rice production of Tk. 49137, 52595, 50777, 56338 and 55003 ha^{-1} against the yield of 4.97, 5.26, 5.24, 5.60 and 5.45 t ha^{-1} for landless, marginal, small, medium and large farmers' categories, respectively. The average per hectare benefit-cost ratio was highest in large farmers' categories followed by medium, marginal, landless and small farmers' categories, and these were 2.42, 2.40, 2.39, 2.38 and 2.34, respectively. The average benefit-cost ratio of those categories was 2.38. It varied from 2.34 to 2.42 for the various categories of farmers. The highest return indicated the profitability of rice production. The average boro rice productivity of the study area was of 5.31 t ha^{-1} which was higher than that of national average (3.965 t ha^{-1}) in Bangladesh (BBS, 2015). Per hectare net return was found 11.7308.50/ha. The highest per hectare net return was found Tk.8161.02 in case of large farms followed by medium (Tk.7570.86) and small (Tk.6404.98) farms, respectively (Khan, 2004).

Table 5. Rice yield and economic returns of sampled farmers' in *haor* area in Bahadurpur village under Sadar upazila of Sunamganj district

Farmers' category, No.	Rice details and income				Gross Return (3+5) (Tk. ha^{-1})	Cost of rice cultivation (Tk. ha^{-1})	Economic return (6-7) (Tk. ha^{-1})	BCR (6/7)
	Grain yield		Straw yield					
	Grain yield (t ha^{-1})	Total (Tk. ha^{-1})	Straw yield (t ha^{-1})	Total (Tk. ha^{-1})				
1	2	3	4	5	6	7	8	
Landless, 10	4.97	67631	6.85	17125	84756	35618	49137	2.38
Marginal, 16	5.26	71577	7.50	18750	90327	37732	52595	2.39
Small, 18	5.24	71305	7.00	18000	88805	38028	50777	2.34
Medium, 15	5.60	76204	8.15	20375	96579	40241	56338	2.40
Large, 6	5.45	74162	7.80	19500	93662	38659	55003	2.42
Total, 65	5.31	72213	7.49	18737	90799	38153	52646	2.38

Local market price: Grain @ 13.61 Tk. kg^{-1}; Straw @ 2.5 Tk. kg^{-1}

Conclusion

A *haor* is a wetland ecosystem in the north-eastern part of Bangladesh which physically is a bowl or saucer shaped shallow depression, also known as a backswamp. Boro rice cultivation in *haor* area was required labourer of 149 man-day ha^{-1}. The average annual income from rice production of sampled farmers was 52646 Tk. ha^{-1}. Productivity of boro rice is low (5.31 t ha^{-1}) due to imbalance use of fertilizers but yield showed higher than that of national average production in Bangladesh due to one cropped area in *haor*.

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Integrated weed management in direct-seeded rice: dynamics and economics

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Abstract

Weeds are often the most severe problem in direct-seeded rice (*Oryza sativa* L.) (DSR), cause reductions in yield and profitability. The traditional method of controlling rice weeds or manual weeding has several demerits as the practice is uneconomical and difficult. The effects of 10 different weed management practices were evaluated to identify the most effective and economical method of managing weeds in DSR in Nepal during the rainy season of 2010. Pendimethalin was applied pre-emergence where 2,4-D, bispyribac sodium, and oxadiargyl were applied post-emergence alone or combined with hand weeding. Sesbania (*Sesbania aculeata* Wild. Pers.) was co-cultured with rice and killed by with using 2,4-D. Weed emergence, density, and biomass per unit area of 3 weed types: broadleaf, sedges, and grasses were assessed during 20, 40, 60 days after seeding (DAS), and at harvest. Treatments were compared either to weedy check or weed-free control to determine weed control indices. A total of 42 weed species belonging to 27 genera and 11 families emerged across the growing season of rice. Most of the weeds were annual where broadleaf and sedges were dominant during the first two months, and grasses were dominant under flooding. Weeds reduced the rice yield by more than 80% in weedy-check with respect to weed-free control. A sequential application of pendimethalin as pre-emergence and bispyribac-sodium postemergence herbicides followed by a hand weeding at 45 DAS provided up to 85% weed control over weedy check than other weed control measures. However, that method found uneconomical when compared to the same without hand weeding because of the high cost of manual labor. Pendimethalin was effective in controlling early flush of weeds and bispyribac efficiently controlled weeds even after flooding turned out to be a less expensive method controlling in DSR. An integrated approach of weed management including both pre-emergence and post-emergence herbicides can provide season-long weed control greater economic return.

Keywords: Direct-seeded rice, Weeds, Herbicides, Hand weeding, Benefit to cost ratio

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Introduction

In Nepal, rice (*Oryza sativa* L.) is widely planted manually by transplanting 20 to 30-days-old seedlings into puddled soil. However, transplanting is becoming increasingly challenging due to unavailability and the high cost of labor and energy, restricted supply of irrigation water, and decline of soil quality (Chauhan, 2012b). Depending on the growing season, climatic conditions, soil types, and hydrological condition, the total seasonal water input for a puddled transplanted rice ranges from 660 to 5280 mm (Bouman and Tuong, 2001). As a result, DSR is gaining in popularity as it is an economical alternative to transplanted rice. Direct-seeding of rice on pulverized soil reduces total labor requirement by 11 to 66%, saves 19 to 24 person-d ha-1, resulting in earlier and easier crop establishment (Rashid et al., 2009). DSR has the potential to reduce water and labor use compared to transplanted rice by eliminating the puddling phase and avoiding continuous standing water (Kumar and Ladha, 2011). Direct seeding reduces irrigation requirements by 30% of the total irrigation water required for transplanted rice (1400 to1800 mm) (Gopal et al., 2010), and results in greater tolerance or rice to water deficit (Yadav et al., 2004). Also, DSR matures 8 to11 d earlier than transplanted rice, which facilitates the earlier establishment of the following winter wheat (Balasubramanian and Hill, 2000).

Despite several advantages, weeds are considered a major biological constraint of DSR systems (Dhakal et al., 2015; Chauhan, 2012a), resulting in inferior yields and poor stand establishment compared to transplanted rice (Singh et al., 2005). More than 50 weed species reported to be a significant cause of yield loss in DSR (Gianessi et al., 2002). It was estimated that rice yields were reduced by 80% (Mahajan et al., 2009), and even up to 100% in DSR compared to transplanted rice when no weed management practices were implemented (Sharma et al., 1977). Weeds compete with rice for light, nutrients, and water, ultimately diminishing crop growth and development. Singh and Dash (1988) reported that an increase in dry weed biomass at the

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rate of 1 g m^{-2} decreased rice yield by 7.4 kg ha^{-1}. The weed interference early in an establishment is especially problematic in DSR owing to the size disadvantage of seedlings relative to weeds and soil water deficit condition. Weeds cause reductions in crop quality by interfering with rice harvest and sometimes makes mechanical harvest impractical. Cyperaceae and Poaceae are predominant, out of 1800 species reported as weeds of rice (Moody, 1989). Dominant weed species in South Asia include *Cyperus rotundus, Fimbristylis miliacea, Ischaemum rugosum, Monochoria vaginalis*, *Comellina* spp., *Echinochloa* spp., *Cynodon dactylon*, *Elucine indica*, in DSR system (Chauhan, 2012b).

Suppression of weeds very early in the season holds the key for a successful DSR (Singh, 2008) as it is described as 'knowledge intensive' practice because of its requirement of a more decisive role in crop management and weed control. Substantial information is required to enable farmers to judge the best scientific options for weed management, especially during the transition from transplanting to direct-seeding (Rao et al., 2007). In Nepal, manual weeding is extensively practiced, which usually starts from 20 to 30 DAS, only after the weeds have reached a sufficient size to be pulled (Rao et al., 2007). But it may trigger late to catch the critical crop-weed competition which is evidenced by yield loss assessments of the effects of manual weeding at 20 to 30 DAS with selective herbicides (Zimdahl, 1999). Labor scarcity, high labor cost, identical growth of weedy grass and rice seedlings, and the presence of perennial weeds that breakout on pulling may all lead to lowered efficacy in manual weeding (Rao et al., 2007).

Use of herbicides is one of the alternatives of manual weeding (Rao et al., 2007) which in recent years has been dramatically increased in South Asia by the spread of DSR (Azmi et al., 2005). Application of pre-emergence herbicide is effective at dry period for early flush of weeds either just before or after rice emergence (Singh et al., 2016; Mahajan and Chauhan, 2015), but for the second flush of weeds at the flood period requires either a post-emergence herbicide application or manual weeding (Jordan et al., 1998). The narrow time window (0 to 3 DAS) demands highly effective pre-emergence herbicides (Mahajan and Chauhan, 2015) to provide season-long weed control (Helms et al., 1995) such as pendimethalin, quinclorac, and thiobencarb. Bispyribac-sodium (bispyribac from now on), 2,4-D, clomazone, halosulfuron, fenoxaprop are the common post-emergence herbicides used to control selective weeds (Rao et al., 2007). Although, oxadiargyl, a protoporphyrinogen inhibitor is a pre-emergence herbicide, which can also be applied either delayed pre-emergence or early post-emergence. Oxadiargyl was found effective in some regions of India and Nepal in controlling grassy weeds (Gopal et al., 2010). The effectiveness of herbicide is limited by its diverse interacting factors such as diverse weed species, weed populations, cultural practices, soil and climatic conditions, and development of herbicide resistance (Moody, 1991). The use of single herbicide may not work for more extended period which often demands change in herbicide mixture in a few years or integration with mechanical methods. We hypothesized that incorporation of pre-emergence and post-emergence herbicide followed by manual weeding is the efficient and economical approach to weed management in DSR. Therefore, the objectives of this research were to 1) describe weeds and their diversity in DSR, and 2) quantify weed density and biomass in response to management practices. Outcomes will contribute, to developing effective weed management strategies for DSR.

Materials and Methods

Study Location

A field experiment was conducted at the Agronomy Research Farm (27.6474^{0}N, 84.3497^{0}E) of the Institute of Agriculture and Animal Science located in Chitwan district of Nepal during the rainy season of 2010. The region is subtropical, with annual average precipitation of about 1620 mm (90% occurs from June to September) (Thapa and Dangol, 1988). The total rainfall received from May to November was 1350 mm with a peak in July (490 mm). The average maximum and minimum temperatures recorded from May to November were ranged from 27.8 to 35.5 and 17.7 to 26.9^{0}C, respectively (NMRP, 2011) (Fig. 1).

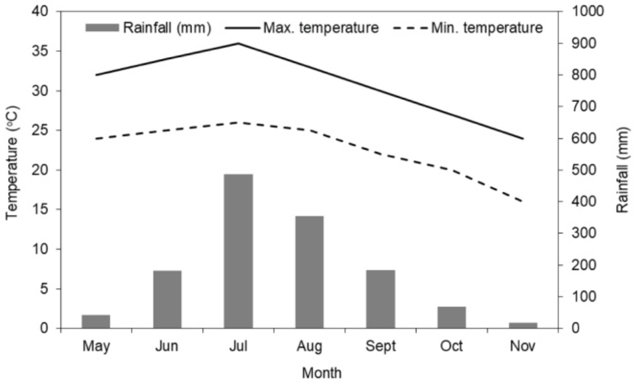

Figure 1. Temperature and rainfall for the seven months period of 2010 recorded at nearby weather station of research location at Chitwan, Nepal.

The soil texture was sandy loam (sand = 60.4 ± 4.4%, silt = 27.3 ± 2.7%, and clay = 12.3 ± 1.2%). The top 20 cm soil was low in organic matter content (2.34 mg g^{-1}) with a slightly acidic pH range of 5.8 – 6.4. Historically, the area was known as the Narayani River floodplain and 'rice superzone area' stated by the government of Nepal. The field was previously fallowed for more than one year and rich in the annual weed seed bank.

Experimental Design and Treatments.

Ten weed management practices including pre-emergence and post-emergence herbicide (Table 1) were evaluated in a randomized complete block design with three replications. Herbicides included in the study were pendimethalin (Stomp® 3.3EC, BASF India Ltd.), 2,4-D (Suspend® 80WP, CACP Ltd. India), bispyribac-sodium (Nominee gold® 10SC, PI Industries), and oxadiargyl (Topstar® 80WP, Bayer Crop Science). The experimental unit consisted of 3 × 4 m (12 m^2) plot, accessed to the controlled surface irrigation system.

Experimental Details

A blanket application of glyphosate (Glykal 41SL, Kalyani Industries Pvt. Ltd.; 1.5 kg ai ha^{-1}) was performed in the first week of May followed by a crisscross plowing with a disc harrow followed by single planking. A light pre-sowing irrigation (10 cm) was provided, 48 h before seeding. The rice cultivar planted was 'Sabitri,' a fine, semi-dwarf (grow up to 1 m tall) which was derived from the cross of IR 1561-228-1/IR 1737//Cr 94-13 (Poudel, 2007). The seed was pre-treated with carbendazim® (Bavistin, 50%WP, Biostadt India Ltd., Mumbai) at a rate of 0.5 g ai kg^{-1}, and hand-seeded in the first week of June at a rate of 40 kg ha^{-1} in light, moist soil at 20 cm row spacing, placed at 2-3 cm deep. The soil was leveled with hand and slightly packed to facilitate germination. On the same day, a legume *Sesbania aculeata* Wild. Pers., native to Asia and North Africa, was co-seeded with rice at a rate of 30 kg ha^{-1}. Fertilizers, 50 kg N, 25 kg $ZnSO_4$ and 30 kg P and K were incorporated into the soil as a basal dose. An additional 50 kg ha^{-1} of N was top-dressed in two splits at 40 and 60 DAS. The field was flooded at 7 days interval prior to the field permanently flooded after an intense rain (> 300 mm) on the third week of July. A detail of applied treatments with their timing and rate of application is provided in Table 1. Pendimethalin was applied as pre-emergence at the rate of 3.3 L ha^{-1}, a few hours after seeding rice. A delayed pre-emergence application of oxadiargyl at a rate of 112 g ai ha^{-1} was done, one week after seeding. Oxadiargyl powder was mixed with sand (20 kg ha^{-1}) and broadcasted similar to a general practice of farmers. All plots were irrigated not more than 3 cm just before oxadiargyl application. Bispyribac and 2,4-D were applied as post-emergence from 20 to 22 DAS (three-to-four leaf stage of rice), one day after third irrigation at the rate of 25 and 1500 g ai ha^{-1}, respectively. Sesbania was killed by 2,4-D ethyl ester at a rate of 500 g ai ha^{-1} at 25 DAS. A battery operated knapsack sprayer fitted with a double boom nozzle was calibrated to deliver 500 L ha^{-1} for pendimethalin and 350 L ha^{-1} for post-emergence spray solutions. A single application of insecticide Endosulfan 350 EC (Thiodan, now banned) at 1 L ha^{-1} was applied before the milking stage of the crop to control rice Gundhi bug (*Leptocorisa oratorius* F.). Weeds removed manually on targeted plots at 45 DAS preceding chemical treatment whereas weed-free plots weeded weekly throughout the season. The above-ground biomass was harvested in the second week of September (125 DAS), cut to 8 to 10 cm stubble height using a hand sickle. Harvest was left on the field for 5 day to allow sun drying. Threshing was done manually. Grains were detached cleaned by winnowing and weighed at their ambient moisture level (17%) to determine yield. Similarly, straw was weighed to account for the total biological yield.

Table 1. Details of treatments applied in DDSR plots in 2010.

Treatment ID	Treatment details	Dose g ai ha^{-1}	Application time DAS
W_1	Weedy-check	NA	NA
W_2	Weed-free	NA	Weekly
W_3	Sesbania fb 2,4-D	500	25
W_4	Pend	3300	0§
W_5	Pend fb HW	3300	0 fb 45
W_6	Pend fb 2,4-D	3300 fb 1500	0 fb 22
W_7	Pend fb 2,4-D fb HW	3300 fb 1500	0 fb 22 fb 45
W_8	Pend fb bispyribac	3300 fb 25	0 fb 22
W_9	Pend fb Bispyribac fb HW	3300 fb 25	0 fb 22 fb 45
W_{10}	Oxadiargyl fb HW	112	7 fb 45

fb = followed by, HW = hand weeding, DAS = days after sowing, Pend = pendimethalin
§ Day zero i.e. on a seeding day

Weed Dynamics

Weed samples were collected using destructive sampling technique during 20, 40, 60 DAS, and harvest inside a 50 cm × 50 cm quadrat at three random locations on each plot. Total weeds were then separated into species fractions (broadleaves, grasses, and sedges) and then counted to determine their dominance based on their density (D) and frequency (F). Weeds were identified with the aid of a standard practical field guide by Caton et al. (2010). Local rice growers assisted in identifying some native weeds, especially during the early vegetative stage. Samples were dried for at least 48 h in a forced air oven at 55°C before weighing. The weed species density was calculated as the number of individual plants per unit area, whereas the total weed density was calculated as the total number of weeds per unit area for particular treatment [Eq. 1].

$$\text{Density (plants m}^{-2}) = \frac{\text{number of plants}}{0.25\ \text{m}^2} \quad [1]$$

Frequency was determined as the presence or absence of weed species within the quadrat. The frequency of individual weed species was determined using a method modified from Misar et al. (2016):

$$\text{Frequency (\%)} = \frac{\text{no. of quadrats containing at least one plant}}{\text{total N of quadrats (90)}} \times 100 \quad [2]$$

Weed control efficiency (WCE) was determined for each treatments using Eq. [6] given by Mani et al. (1973) which expresses the percentage reduction in weed population due to weed control methods over the unweeded check.

$$\text{Weed control efficiency (\%)} = \frac{WP_c - WP_t}{WP_c} \quad [3]$$

where WP_c is weed population (plants m^{-2}) in an unweeded plot and WP_t is the population in the treated plot. Weed index (WI) was determined for each treatment as the reduction in grain yield due to the presence of weeds in comparison with no weed plot. Crop grain yield was determined and corrected to 12% moisture. Weed index was calculated as suggested by Gill and Vijay Kumar (1969) using Eq. [4].

$$\text{Weed index} = \frac{X - Y}{X} \times 100 \quad [4]$$

Where X and Y are the crop grain yield (Mg ha^{-1}) from weed free plot and treated plots, respectively.

Economic Analysis

Cost of cultivation was calculated from current local charges for different agro-inputs such as labor, fertilizer, compost, diesel, electricity, and farm equipment including 5% contingency measures. Similarly, gross return was determined for the economic yield (grain + straw) of rice on the basis of the current local market price.

Then benefit to cost ratio was determined as the ratio of gross return to the cost of cultivation [Eq. 5] which also expressed as the return per dollar (transacted in rupee) invested (Reddy and Reddi, 2002). B:C ratio greater than 2.0 would consider economically ideal for farm business management for most of the agricultural commodities. That means farmers would get $ 2.0 for every dollar invested.

$$\text{B:C ratio} = \frac{\text{Gross return (USD)}}{\text{Total cost of cultivation (USD)}} \quad [5]$$

Statistical Analysis

Weed density or count data were square root transformed $\sqrt{(x+1)}$ before analysis because they were discrete and the distribution was right-skewed. The weed frequency distribution was binomial. Thus, the GLIMMIX procedure was used to analyze the data in SAS 9.4 (SAS Institute, Cary, NC) where the default link function was 'logit' (Stroup, 2015). Treatments were set as fixed effects and replication was configured as a random effect (Littell et al., 2006). Treatment means were compared at α = 0.05 using Least Significant Difference test at $P \leq 0.05$.

Results and Discussion

Weed Emergence

A total of 42 weed species belonging to 27 genera within 11 families were identified across the growing season of rice on the field (Table 2). The dominant weed species observed were belonging to the Poaceae family (15 spp.) followed by Cyperaceae (13 spp.), Compositae (3 spp.), Amaranthaceae and Commelinaceae (2 spp. each) and others (7 spp.). Overall, 13 broadleaf weed (BLW), 14 sedges, and 15 grass species were recorded in the field. Based on density and frequency, the dominant weed species were *Echinochloa colona* (L.) Link, *Digitaria ciliaris* (Retz.) Koel., *Paspalum brevifolium* Flugge, *Cynodon dactylon* Pers., *Ischaemum rugosum* Salisb., and *Eleusine indica* (L.) Gaertn. among grasses; *Commelina benghalensis* L., *C. diffusa* L., *and Monochoria vaginalis* Burm. among the broadleaf and *Fimbristylis miliacea* Vahl., *Scirpus juncoides* Roxb., and *Cyperus* spp. among the sedges.

Table 2. Description of the observed weed species, their emergence time, population density, and frequency in DSR. Density and frequency of weeds were averaged over multiple sampling dates and replications.

Scientific name	Family	Group	Density	Frequency	Emergence time			
					20	40	60	H
			Plants m^{-2}	%	DAS			
Aeschynomene indica L.	Fabaceae	Broadleaf	3	6	–	+	–	–
Ageratum conyzoides L.	Compositae	Broadleaf	4	11	+	+	+	–
Alternanthera sessilis R. Br.	Amaranthaceae	Broadleaf	3	7	–	+	+	–
Amaranthus viridis L.	Amaranthaceae	Broadleaf	2	4	+	–	–	–
Caesulia axillaris Roxb.	Compositae	Broadleaf	8	8	+	+	+	+
Centella asiatica (L.) Urb.	Apiaceae	Broadleaf	3	4	–	–	+	+
Commelina benghalensis L.	Commelinaceae	Broadleaf	94	97	+	+	+	+
Commelina diffusa L.	Commelinaceae	Broadleaf	32	64	+	+	+	–
Euphorbia hirta L.	Euphorbiaceae	Broadleaf	7	17	+	+	+	+
Ipomoea aquatica Forsk.	Convulvulaceae	Broadleaf	4	22	–	+	+	–
Melochia corchorifolia L.	Sterculiaceae	Broadleaf	2	12	+	+	–	–
Monochoria vaginalis Burm.	Pontederiaceae	Broadleaf	9	14	–	+	+	–
Phyllanthus fraternus Webs.	Euphorbiaceae	Broadleaf	5	11	+	+	–	–
Bulbostylis barbata Clarke	Cyperaceae	Sedge	7	7	–	–	–	+
Cyperus brevifolius Hassk.	Cyperaceae	Sedge	2	10	+	+	–	–
Cyperus compressus L.	Cyperaceae	Sedge	1	9	–	+	–	–
Cyperus difformis L.	Cyperaceae	Sedge	47	56	–	+	–	–
Cyperus esculentus L.	Cyperaceae	Sedge	2	4	–	+	+	–
Cyperus flavidus Retz.	Cyperaceae	Sedge	4	6	–	–	+	+
Cyperus halpan L.	Cyperaceae	Sedge	14	20	+	+	+	–
Cyperus iria L.	Cyperaceae	Sedge	4	2	–	+	+	–
Cyperus pilosus Vahl.	Cyperaceae	Sedge	3	3	–	+	–	–
Cyperus rotundus L.	Cyperaceae	Sedge	117	96	+	+	+	+
Fimbristylis dichotoma Vahl.	Cyperaceae	Sedge	6	4	–	+	+	–
Fimbristylis miliacea Vahl.	Cyperaceae	Sedge	43	39	–	+	+	+
Scirpus juncoides Roxb.	Cyperaceae	Sedge	55	37	–	–	+	+
Scirpus mucronatus L.	Cyperaceae	Sedge	9	4	–	+	+	+
Brachiaria ramosa Stapf.	Poaceae	Grass	15	10	+	+	–	–
Chrysopogon aciculatus Retz.	Poaceae	Grass	7	10	+	+	+	–
Cynodon dactylon Pers.	Poaceae	Grass	25	22	+	+	+	+
Dactyloctenium aegyptium L.	Poaceae	Grass	11	11	+	–	–	–
Digitaria ciliaris (Retz.) Koel.	Poaceae	Grass	58	54	+	+	–	–
Echinochloa colona (L.) Link	Poaceae	Grass	109	70	+	+	+	–
Echinochloa crusgalli L.	Poaceae	Grass	4	3	+	+	–	–
Eleusine indica (L.) Gaertn.	Poaceae	Grass	23	22	–	+	+	+
Eragrostis tenella P. Beauv.	Poaceae	Grass	12	13	+	+	–	–
Ischaemum rugosum Salisb.	Poaceae	Grass	3	3	+	+	–	–
Leersia hexandra Sw.	Poaceae	Grass	11	11	–	–	+	–
Paspalum brevifolium Flugge	Poaceae	Grass	26	24	+	+	+	–
Paspalum scrobiculatum L.	Poaceae	Grass	2	4	+	+	+	–
Setaria glauca (L.) P. Beauv.	Poaceae	Grass	8	3	+	–	–	–
Seteria pallid–fusca Schum.	Poaceae	Grass	13	7	–	–	+	–
Total number of species = 42	Family = 11		N = 817					

H, harvest; DAS, days after sowing; N, total number of weeds m^{-2}

Grasses dominated weed flora as they comprised 41% of the total weed population whereas BLW and sedges consisting of 37% and 22%, respectively. Grasses were emerged as early flush and abundant although the density was not significant than sedges and broadleaf because of the previous seed bank of grasses and appropriate moisture content of the soil as the field was non-flooded for the first month of seeding. At 40 DAS, all categories of weeds appeared in equal proportion. The third flush of weed was counted at 60 DAS after the hand weeding on 45 DAS, mostly characterized by broadleaf and sedges as the grass population started to decline due to standing water in the field. Broadleaves such as *Monochoria vaginalis* Burm. emerged significantly after continuous irrigation whereas *Commelina* spp. began decreasing continuously but appeared throughout the season. *Cyperus rotundus* L. was the most frequently observed weed followed by *Echinocloa colona* (L.) Link and *Commelina benghalensis* L.

Weed species such as *Cynodon dactylon* L., *Cyperus* spp., and *Commelina* spp. may emerge earlier when they receive adequate soil moisture. Pendimethalin applied pre-emergence controlled a significant number of broadleaf and sedges but didn't show any effect on *Cynodon dactylon* L. and *Echinocloa* spp., which were even flush out significantly, two weeks after sowing. Sedges and grasses were dominant in 2,4-D applied plots. Sesbania co-culture was effective against grasses, broadleaf, and few sedges. Almost all families of weeds observed in control and oxadiargyl treated plots. In control plots, broadleaf comprised nearly 65% of all the species. Bispyribac favored sedges while *Cynodon dactylon* L. consistently appeared in plots treated with pendimethalin alone and oxadiargyl.

The primary reason that affects the dynamics of weed population emergence and its subsequent establishment depends on many new recruitments as a fresh seed rain or existing weed-seed bank (Naylor, 2002). Singh (2008) reported that broadleaf weeds dominated the first 30 DAS than grasses and sedges, constituting more than 62% of the total weed composition and indicated emergence from the pre-existing seed bank. Singh et al. (2016) reported 50% ground coverage owing to broadleaf weeds followed by grasses (15%) and sedges (5%) at 45 DAS. Kim et al. (1997) also recorded similar types of weed species in DSR where annual grasses were the predominant weeds, such as *Echinocloa* spp., *Digitaria adscendens* (Kunth) Henrard, *Leptochloa chinensis* L., and *Setaria viridis* (L.) P. Beauv., including weedy rice (*O. sativa* L. subspp. *spontanea*). Sedges and grasses can survive continuous flooding to a water depth of 10 cm; however, in our study, a week of flooding during peak monsoon eliminated some grass and broadleaf species. At harvest, the majority of grasses were disappeared from all plots except on control, which had a thin stand of a crop. The weed community was so diverse that only integrated approach of management would give satisfactory results, enough to justify the treatments applied.

Weed Density

Weed management strategies affected the total weed population density across the rice growing period (Table 3). Pendimethalin was superior in controlling early flushes of weeds at 20 DAS. Bispyribac and 2,4-D were equally effective following pendimethalin in reducing postemergence weeds at 40 and 60 DAS even without additional hand weeding. Pendimethalin alone, sesbania co-culture, and oxadiargyl couldn't suppress weed population during mid and late season when the second flush of weed emerged after flooding rice field. Most of the sedges appeared after the first hand-weeding showed greater weed density in plots treated with pendimethalin than broadleaf and grasses. Bispyribac effectively killed deep-rooted sedges as they resist manual weeding because of their breakable culm and deep-set of knots. Post-emergence herbicides, 2,4-D, and bispyribac provided excellent control of weeds starting 20 DAS up to harvest. Combination of hand weeding provided an opportunity to remove grassy weeds where grasses tended to survive post-emergence herbicide, especially *Cynodon dactylon* L.

Table 3. Total weed population as affected by different weed management practices during 20, 40, 60 DAS, and harvest of DSR in Chitwan, Nepal.

Treatment	Total weed density			
	20 DAS †	40 DAS	60 DAS	Harvest
	plants m^{-2}			
Weedy-check	784 a§	1000 a	557 a	189 a
Weed-free control	-	-	-	-
Sesbania followed by 2,4-D	613 b	352 c	225 b	160 b
Pendimethalin	229 d	529 b	248 b	136 c
Pendimethalin followed by HW	274 d	581 b	101 cd	41 fg
Pendimethalin followed by 2,4-D	244 d	315 cd	221 b	96 d
Pendimethalin followed by 2,4-D followed by HW	223 d	305 cd	126 c	56 ef
Pendimethalin followed by bispyribac	216 d	186 e	80 cd	102 d
Pendimethalin followed by bispyribac followed by HW	273 d	244 de	52 de	26 g
Oxadiargyl followed by HW	396 c	524 b	86 cd	64 e
LSD ($P < 0.05$)	113	76	63	16
Mean	325	404	170	87

† DAS, days after seeding
HW, hand weeding
§ Treatment means followed by different lowercase letters are different at $P < 0.05$.

Weed density and biomass determine the extent of crop-weed interference, yield, and quality of the harvest. An effective weed management method should ensure a weed density and biomass below an economic threshold (IRRI, 1967). Sesbania co-culture reduced the plant density by 50% as compared to weed-free plot and created an environment favorable for weeds. Singh et al. (2007) reported that *Sesbania* intercropping caused a 37% reduction in total weed biomass at 75 DAS. Controlling late flushes of weeds with postemergence herbicides such as bispyribac and 2,4-D gave superior results. Hussain et al. (2008) reported that among four herbicidal treatments viz. SunStar Gold 60 WG at 200 g ha^{-1}, a rice field treated with a postemergence application of bispyribac applied at 15 and 25 DAS produced the lowest weed biomass when compared to pre-emergence herbicides. Suria et al. (2011) reported that pendimethalin treated plots had the lowest (80 plants m^{-2}) weed density than control. Singh et al. (2016) reported the lower weed density in plots treated with pendimethalin (10 to 13 plants m^{-2}) at 20 DAS than others because of the lowest record of broadleaf weeds and sedges. Oxadiargyl caused necrosis of rice leaves and increased tiller mortality that reduced the ability of rice to suppress weeds. In a greenhouse experiment, Gitsopoulos and Froud-Williams (2004) reported a significant rice crop sensitivity to oxadiargyl when applied at more than 100 g ha^{-1} under dry seeding. Dario and Gallo (1999) noted similar phytotoxic symptoms such as stunting of rice plants, slower growth and brown spots on the main culm and leaf up to 60 DAS in Brazil. It was also reported that bispyribac at the rate of 25 g ha^{-1} provided excellent control of grasses and sedges, and total weeds (Schmidt et al., 1999). Mahajan and Chauhan (2015) reported lower sedges density (5 plants m^{-2}) in the plots treated with bispyribac at 25 g ha^{-1} compared to 32 and 29 plants m^{-2} in plots treated with pendimethalin and fenoxaprop, respectively. Similar result was reported by Ranjit and Suwanketnikom (2005) and Gill et al. (1996) where they found excellent control of grass (*Echinochloa* spp.) and sedges (*Cyperus* spp.) using bispyribac at higher rates (25-30 g ha^{-1}) at an early application timing (15-20 DAS).

Weed Biomass

Dry biomass is the best way of expressing weed dominance as this method is less sensitive to the sampling frame than density. For example, a single culm of *Commelina* spp. may equal tens of *Fimbristylis* spp. with respect to biomass. Biomass provides information about the accumulation of the growth and use of nutrients from the soil. The biomass of grasses, broadleaf, and sedges was lower with 2,4-D and bispyribac alone or in integration with manual weeding compared to weedy check, sesbania co-culture, pendimethalin only, and oxadiargyl (Table 4). A sequential application of 2,4-D or bispyribac following pendimethalin equally reduced the total weed biomass greater than pendimethalin alone, oxadiargyl, and sesbania co-culture. Integrated weed control by combining pre- and post-emergence herbicides and hand weeding, effectively controlled the weed biomass throughout the season.

Table 4. Total weed biomass as affected by different weed management practices during 20, 40, 60 DAS, and harvest of DSR in Chitwan, Nepal.

Treatment	Total weed biomass			
	20 DAS †	40 DAS	60 DAS	Harvest
	g m^{-2}			
Weedy-check	163.8 a§	340.6 a	224.2 a	48.8 a
Weed-free control	0.0 d	0.0 f	0.0 e	0.0 h
Sesbania followed by 2,4-D	147.8 a	114.0 c	85.4 b	36.2 b
Pendimethalin	51.1 c	187.4 b	102.6 b	28.8 c
Pendimethalin followed by HW	51.9 c	193.7 b	40.7 cd	8.7 f
Pendimethalin followed by 2,4-D	44.1 c	107.6 cd	86.0 b	21.8 d
Pendimethalin followed by 2,4-D followed by HW	43.3 c	95.4 cd	51.5 c	11.8 ef
Pendimethalin followed by bispyribac	43.2 c	62.8 e	38.5 cd	19.1 d
Pendimethalin followed by bispyribac followed by HW	51.3 c	83.1 e	21.9 de	4.8 g
Oxadiargyl followed by HW	91.2 b	188.1 b	35.1 cd	14.2 e
LSD ($P < 0.05$)	24.1	29.0	24.8	3.9
Mean	68.7	137.5	68.7	19.5

† DAS, days after seeding
HW, hand weeding
§ Treatment means followed by different lowercase letters are different at $P < 0.05$.

Bispyribac was found superior in controlling sedges, grasses and total weed biomass than others at 60 DAS indicated that it could work even at standing water. The post-emergence application of 2,4-D was found effective in controlling broadleaf weeds comparable with the bispyribac. Sesbania co-culture and a single application of pendimethalin were found weaker in reducing weed infestation throughout the season. Oxadiargyl followed by hand weeding performed in between pre-emergence and post-emergence herbicides. Hand weeding gave added benefits to the herbicide application although it is considered uneconomical. A single application of pre or post-emergence herbicide may not result in superior outcome. Singh et al. (2016) who reported initial effectiveness of pre-emergence herbicides such as pendimethalin and oxadiargyl alone but their performance declined 45 DAS. The post-emergence application of bispyribac and azimsulfuron was found superior either applied alone or in sequential with pre-emergence in controlling all kinds of weeds throughout the season. The grass component in the weed community increased significantly after one month of seeding. Mahajan et al. (2009) also found that the subsequent application of pendimethalin at 1 kg ha^{-1} followed by bispyribac at 30 g ha^{-1} applied 15 DAS resulted in significant control of weeds in DSR. Walia et al. (2008) also reported pendimethalin at 750 g ha^{-1} followed by bispyribac 25 g ha^{-1} resulted in a 372% increase in rice grain yield than weedy-check. McCauley et al. (2005) also observed that without supplementation of post-emergence herbicide with the pre-emergence the chances of crop yield reduction can be increased from 9 to 60% compared to a weed-free condition. Singh et al. (2005) emphasized the importance of the sequential application of pendimethalin as pre-emergence and chlorimuron + metsulfuron as post-emergence in realizing reduced grass population. The research results are in line with the previous studies of superior weed management in direct seeded rice with the application of pendimethalin followed by bispyribac (Mahajan and Chauhan, 2013; Ganie et al., 2013). The sequential application of pendimethalin and 2,4-D was also found superior comparable with the bispyribac. The results also indicated that one hand weeding had an added benefit of realizing weed control in combination of herbicides. Current results are in line with Mann et al. (2004) who reported effective control of weeds with pendimethalin followed by 2,4-D in DSR. Although this research found sesbania co-culture inferior in controlling weeds than other methods, Ghosh et al. (2017) observed significant weed control by sesbania co-culture, 65% more weed control than weedy-check when followed by pendimethalin and then 2,4-D. Combining pre- and post-emergence herbicides in a sequence may provide effective weed control in DSR.

Weed Control Efficiency and Weed Index

The WCE and WI for the entire growing season were compared among treatments (Fig. 2). Sesbania co-culture was found the weakest among the treatments which had only 37% efficiency in controlling weeds. Similarly, pendimethalin alone was also ineffective in controlling the weeds. In contrast, integrated weed control combining both pre- and post-emergence herbicides along with hand weeding resulted in WCE ranged from 77 to 88%. The sequential application of pendimethalin followed by either bispyribac or 2,4-D resulted in inferior results than the additional hand weeding. Oxadiargyl showed greater WCE than pendimethalin alone and the sesbania co-culture. The WI or reduction in yield due to crop-weed competition ranged from 14% in pendimethalin followed by bispyribac followed by hand weeding to 82 % in weedy check (Fig. 2). The *Sesbania* co-culture with rice showed higher yield reduction similar to oxadiargyl compared to other treatments. The higher weed density and the smothering effect of sesbania to the crop could be the reason for low WCE and a higher WI in the brown-manuring plots.

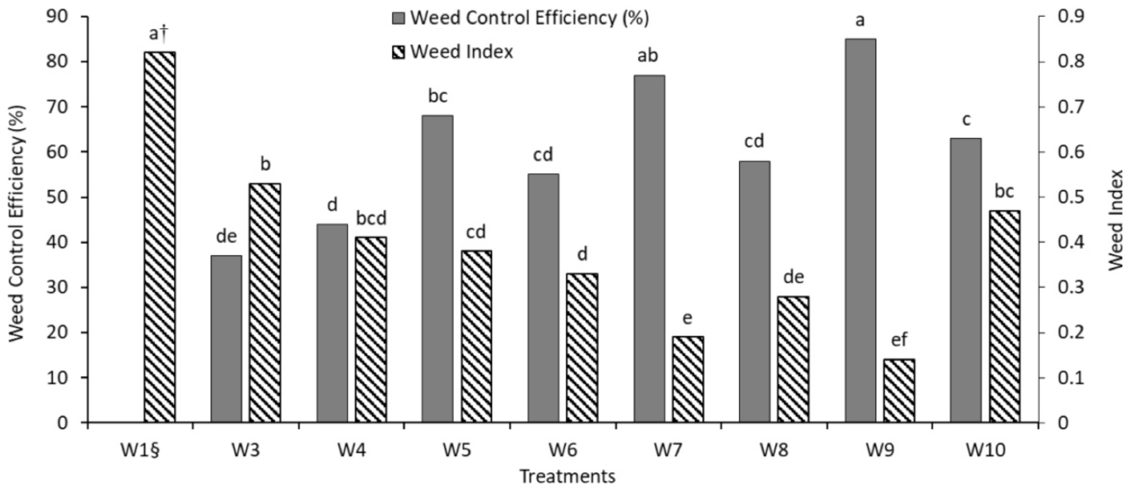

Figure 2. Weed control efficiency and weed index of weed management strategies in DSR at Chitwan, Nepal. § W1, weedy-check; W2, weed-free control; W3, sesbania co-culture; W4, pendimethalin; W5, pendimethalin + hand weeding; W6, pendimethalin + 2,4-D; W7, pendimethalin + 2,4-D + hand weeding; W8, pendimethalin + bispyribac sodium; W9, pendimethalin + bispyribac sodium + hand weeding; Oxadiargyl + hand weeding. † Treatment means followed by different lowercase letters are different at $P < 0.05$.

The efficacy of currently available narrow-spectrum rice herbicides is limited when they are used alone (Singh, 2008; Chauhan, 2012b) and hardly provide season-long weed control (Khaliq et al., 2011). Sesbania co-culture wasn't familiar practice to local growers. One of the reasons highlighted by Kumar et al. (2013) was the smothering effect of sesbania to rice. Singh et al. (2007) reported 20 to 33% lower grass densities and 76 to 83% lower broadleaf densities with sesbania co-culture. The result was supported by Mishra and Singh (2008), who reported lower grain yield (2.37 to 2.67 Mg ha^{-1}) with integration of sesbania with 2,4-D and fenoxaprop compared to other weed control treatments. The higher WI with an early post-emergence application of oxadiargyl was due to reduced yield caused by crop injury from the herbicide treatment. Chauhan (2012b) described oxadiargyl as narrow-spectrum herbicides, reported low efficacy when used alone, and suggested that they do not give season-long weed control. Gitsopoulos and Froud-Williams (2004) reported greater activity of oxadiargyl under wet conditions, and Dickmann et al. (1997) noted that this herbicide can be adsorbed by the soil colloids and can form a shallow herbicidal layer that inhibits weed seed germination. In contrast, Ramana et al. (2007) reported positive results where they found the lowest weed index (8.8%) following oxadiargyl treatment. An integrated approach using herbicides with a different mode of action was advocated by Maity and Mukharjee (2008) to combat weed menaces in DSR and prevent changes in weed community structure where they reported 81 and 86% WCE with integrated weed management during 30 and 60 DAS compared to single applications of pre- and postemergence herbicides. The higher yield can achieve from the consistent reduction of weed population resulting from herbicides integrated with a physical method.

Economic Analysis

Cultivation cost for DSR from field preparation to grain harvest differed among treatments (Table 5). Herbicide application involved the cost of labor and chemical. Hand weeding cost was calculated from person hour needed to do the job. Weed-free control had greater gross and net return but resulted in low B:C ratio due to high cost of production. Weedy-check had a net loss of 191 USD over production cost whereas all weed control treatments were able to provide net positive returns. Among integrated weed control methods, pendimethalin followed by bispyribac and hand weeding had greater value close to 2,4-D preceding pendimethalin and followed by hand weeding. Net return and B:C ratio close to 2 (1.94) were greater with pendimethalin followed by bispyribac than that followed by one hand weeding and other weed control treatments. Sesbania co-culture and oxadiargyl followed by hand weeding had low economic return than other integrated approaches.

Table 5. Cost, gross return, net return, and B:C ratio as influenced by weed management practices in DSR at Chitwan, Nepal. Amount shown are in US dollar.

Treatments	Production cost	Gross return	Net return	B:C Ratio
	$ ha^{-1}			
Weedy-check	413	222 e	-191 g	0.54 e
Weed-free control	898	1171 a	273 c	1.30 c
Sesbania followed by 2,4-D	538	590 d	52 ef	1.10 d
Pendimethalin	488	630 d	142 de	1.29 c
Pendimethalin followed by HW	562	744 cd	182 d	1.32 c
Pendimethalin followed by 2,4-D	521	917 bc	396 b	1.76 b
Pendimethalin followed by 2,4-D followed by HW	605	1033 abc	428 b	1.71 b
Pendimethalin followed by bispyribac	547	1063 ab	516 a	1.94 a
Pendimethalin followed by bispyribac followed by HW	620	1093 ab	473 ab	1.76 b
Oxadiargyl followed by HW	530	609 d	78 e	1.15 d
LSD ($P < 0.05$)	-	147	70	0.15
Grand mean	572	807	235	1.39

HW, hand weeding

§ Treatment means followed by different lowercase letters are different at $P < 0.05$.

One of the advantages of the DSR system had been observed as all the treatments were yielding low to satisfactory (B:C ratio 1.1 to 1.94) levels of economic benefit. The ratio implied that there was at least no loss which would be opposite if the crop was transplanted rice because of the high cost of labor and irrigation. In a study conducted by Dhakal et al. (2015) in Nepal reported that the farmers of 8 districts in Terai region realized lower B:C ratio with transplanted rice as compared to DSR. Pre-emergence application of pendimethalin followed by a post-emergence bispyribac controlled early and late flush of weeds effectively which mirrored into the greater crop productivity and economic returns as compared to the less efficient methods of weed control. The result was in conformity with Hussain et al. (2008), they reported the highest net benefit with the application of bispyribac followed by Sunstar Gold while the lowest net gain was observed at an unweeded-check plot. Hasanuzzaman et al. (2008) reported that the maximum cost of integrated weed control was hand weeding due to the high cost of labor in India. The economic analysis also showed that the application of herbicide maximized the profit and B:C ratio. They also added that herbicidal treatments were more profitable than hand weeding, and maybe an alternative in controlling weeds more easily and cheaply when there is a labor crisis.

Conclusions

The DSR hosted all kinds of weeds across the rice season with a complex mixture of BLW, sedges, and grasses. However, a few weed species such as *Cynodon dactylon* L., *Commelina* spp., and *Cyperus* spp. remained dominant throughout the rice growing period. Weeds can potentially reduce the DSR yield by 82% if not controlled. Herbicides can be effective up to 85% of the weed-free measure if integrated with manual weeding. Pendimethalin followed by bispyribac and hand weeding may provide excellent weed control where bispyribac found effective in killing almost all types of weeds except few grass species. Oxadiargyl and sesbania co-culture with rice performed poorly as these methods also had a low economic return. Although the post-emergence application of bispyribac along with hand weeding had greater weed control and high gross profit, net return was little due to the high cost of labor which also lowered B:C ratio. Nevertheless, hand weeding could be a feasible option for farmers if they have a small area of operation. But for large commercial farms, the only option is to adopt the sequential application of pendimethalin and bispyribac because it allows massive farm mechanization with high net returns and eventually solve the problem of the labor crisis. Integrating a pre-emergence herbicide application with post-emergence appeared to have the best potentiality in controlling DSR weeds.

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Conflict of Interest

There is no conflict of interest among parties involving in this project and between authors synthesizing the paper.

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Research Article

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Textural characteristics of organic sweetpotato (*Ipomoea batatas*) cultivars as affected by different thermal processing methods

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Abstract

Different processing methods particularly thermal treatments would impact the potato texture distinctly thus understanding the influence of different thermal treatments on textural characteristics of sweetpotato is needed. Six varieties of sweetpotato were grown on the organic farm and subjected to three thermal treatments (baking, pressure cooking and open cooking). Baking was done in an oven. Pressure cooking was done with a pressure cooker and open cooking was done using a vessel of water. Textural parameters were recorded with a texture analyzer. Objectives were to evaluate the impact of different thermal processing techniques on textural properties of sweetpotatoes and to generate the texture profile analysis of cooked potatoes. Cohesiveness (0.08-0.12%), gumminess (1.96-54.71) and chewiness (0.89-45.39) were highest in baked treatments while hardness (61.24-475.55N) and resilience (0.02-0.11%) were highest in open cooked treatments. Hardness, gumminess, chewiness and resilience reduced with pressure cooking. Based on these results desirable sensory properties can be optimized to maximize consumer acceptance.

Keywords: Sweetpotato, Texture, Cooking, Hardness, Texture Profile Analysis

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Introduction

Among the important food crops produced worldwide, sweet potato (*Ipomoea batatas* L.) is ranked seventh (Button 2015) and thus it plays an important role in global food security. There are various species of sweetpotato with diverse sensory attributes, in terms of taste, mouthfeel characteristics (Sato, 2016; Nwosisi et al. 2016). Different cooking techniques (frying, baking, roasting, microwave, steaming and boiling) have a major impact on taste and the quality of the edible product in general (Sugri et al. 2012). As they result in variations in the material, chemical and sensory qualities of the end produce (Vitrac et al. 2000; Fontes et al. 2011). Thus, research on the elements influencing the quality standards of sweetpotato in terms of the sensory attributes (flavor and texture) and the consumer preference are important to generate sales profit (Sato, 2016). Van Oirschot et al. (2002) assessed the sensory qualities of various cultivars of orange fleshed sweetpotaotes and found that the primary attributes that segregated between the distinctive cultivars were fundamentally identified with the diversity in textural characteristics. Texture Profile Analysis (TPA) is a test designed to mimic food in the mouth and texture analyzer measures the characteristics of force relative to the texture of food, providing outcomes that are insightful and without bias (Liu & Li, 2010). It is thus essential to research how the textural attributes of various cultivars of sweetpotato are related (Sato, 2016). The prime objective of this present research is to investigate the TPA textural parameters of sweetpotato varieties as affected by various thermal processing methods. Six sweetpotato cultivars with different flesh colors were assessed to: 1) evaluate the impact of different thermal processing techniques such as baking, pressure cooking, open cooking on textural characteristics. 2) To generate the texture profile analysis of cooked potatoes using a texture analyzer.

Materials and Methods

Six sweetpotato cultivars of various flesh and texture attributes were gathered toward the conclusion of the 2016 cultivation season from the Tennessee State University, Nashville TN certified organic farm. Production practices applied were done following the regulations of the National Organic Program. Cultivars were Burgundy and Carolina Ruby (red skin and orange flesh); Beauregard, Ginseng and Golden Nugget (copper rose skin and orange flesh) and the non-conventional Asian kind, All Purple (purple skin with purple flesh). Sweetpotato slips were purchased from Jones Family Farms, Bailey, N.C., Slade Farms, Surrey, V.A., Barefoot farms, T.N. After harvest, root curing was done at 13-16°C and 80-90% humid conditions for 5-7 days and set aside for eight weeks before conducting the experiment. Sweetpotato roots were graded according to USDA grading standards. As sweet potatoes differ in size, only samples that

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had similar magnitude and shape were chosen for the examination. For each cultivar, three roots of U.S. no 1 petite size (greatest measurement 2.25 inches, most extreme length 7 inches) were chosen indiscriminately and washed with tap water preceding use in test.

Sweetpotato cooking methods and experimental design

The open/non-conventional cooking technique, pressure cooking and baking were the three cooking techniques applied in this research experiment. Distilled water was utilized as a part of cooking to keep ions from affecting the firm structure of the sweetpotato cultivars.

Open Cooking

Open cooking was performed specifically on high heat with a 2-L stainless steel pot containing 20 oz. to 38 oz. of bubbling water and they were cooked without peeling their skins (Leighton et al. 2008). No top cover was utilized for pots in the open cooking technique. Cooking time differed slightly among the cultivars. A fixed time of 20 minutes was employed.

Pressure cooking

Pressure cooking was done in a 2-L stainless steel pot, with 20-38 ounces of water and they were cooked without peeling their skins (Leighton et al. 2008). Cooking pots were secured with the customary top for pressure cooking. In pressure cooking the temperature used was 100 °C and with similar specific time of 20 minutes.

Baking

Baked samples were heated in aluminum container at 204°C for 90 min within an oven. Cooking duration was chosen with the assistance of sensory tests (Leksrisompong et al. 2012). And finally in order to compare the different cooking procedures, the final product temperature was kept constant. The internal product temperature was kept constant for all treatments in order to compare the different processing / heat treatments. Several experiments were conducted to fix the final internal product temperature.

Instrumental profile analysis

After cooking, all sweetpotato were left to cool at room temperature, then peeled, diced into one-inch cube square samples and put away in independently sealed and labelled polythene bags to prevent loss of moisture before completing instrumental examination. Texture Profile Analysis (TPA) was finished utilizing a texture analyzer TA-HD Plus (Texture Technologies, USA), utilizing a level plate 40 mm in breadth. The samples were packed to 75% of their unique stature by two continuous compressions. The crosshead speed was set at 1.66 mm/sec. Configured height was at 50 mm. Pre-test speed was set at 1.00 mm/sec while post-test speed was 5.00 mm/sec. Testing compression was done as follows. The plate approaches the specimen (1 inch cube) from the calibrated height (50mm) with the pre-test speed; packs it to half of the original height with test speed; plate goes back to the original position using post-test speed. Once the test is finished, the pulverized example was expelled, and the stage surface was cleaned to evacuate the extracted dampness or water. At that point, the next specimen was set underneath the plate. For each cultivar, three different treatments (open cooking, pressure cooking and baking) were applied. Three samples for each treatment was tested. Care was taken to guarantee the specimen removed from the plate when the plate finished the second compression cycle and came back to its underlying position.

Progressively, texture profile of the various sweetpotato samples prepared using different cooking strategies (Fig. 1) were examined for: (1) Hardness (N), the highest force at the primary compression (height of first peak); (2) Cohesiveness, the proportion ratio of the regions of the two resistance ridges (Area 2/Area 1); (3) Gumminess (Hardness * Cohesiveness); (4) Springiness is distance 2/ distance 1 (Springiness is the regained height of the specimen after the compressive exertion is removed (Bourne, 1978), calculated as the ratio of the compression distance regained between the primary and secondary compression (Montejano et al. 1985). (5) Resilience (Area4/ Area3) (6) Chewiness (Gumminess * Springiness).

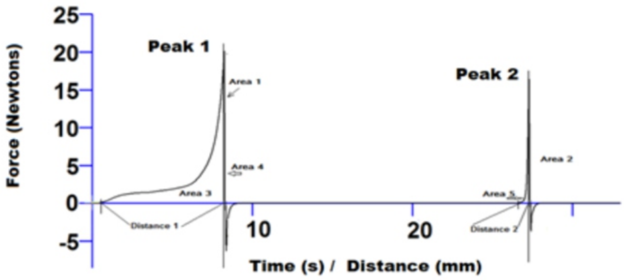

Figure 1. Typical texture profile analysis (TPA) sweet potatoes indicating texture parameters

Data analysis

Data collection and calculation were accomplished using exponent software of the texture analyzer. Instrumental texture parameters from the force versus time curves were recorded in triplicates. Three sweetpotatoes per cultivar were analyzed in each treatment. Data from the texture profile analysis were combined for analysis of variance (ANOVA) using PROC GLM in SAS (Ver. 9.4, SAS, Inc., Cary, N.C.) to determine significant influences of primary parameters-cultivar and cooking methods on the secondary parameters of hardness, and springiness. cohesiveness, gumminess, chewiness, and resilience. If interactions of cultivar and cooking methods were significant, they were used to explain the results. Fisher's least significant difference (LSD) (Fisher, 1939) test was used for multiple comparisons between mean values of the variables cultivar and cooking methods.

Results and Discussion

An analysis of variance (ANOVA) was performed to highlight the characteristics and significant texture differences observed for each sample. Regardless of flesh color, the sizes of the US. no 1 Petite sweetpotato roots employed in this study were not significantly different from each other (Table 1). The results also depicted the cultivar had no significant effect on the sizes of the sweetpotato roots (Table 2). Texture analyses were performed on cooked slices of the six sweet potato samples.

Open cooking

Hardness and resilience were observed to be highest, while cohesiveness had the lowest values among the open cooked treated sweetpotato cultivars (Table 3).

Pressure cooking

Hardness, gumminess, chewiness and resilience were found to be reduced significantly in pressure cooking when compared to other cooking methods (Table 3).

Baking

Cohesiveness, gumminess and chewiness were highest in the baked treatments (Table 3). Different methods of cooking are impacted by a blend of various factors, like temperature and time, thus when comparing various cooking techniques, care should be taken as outcomes will fluctuate due to the type of cooking treatment applied and the food product being prepared (Bernad, 2013). The deciding factor for the texture of plant substances are the cell wall's properties, magnitude and spread of vesicles within the cell's cytoplasm and the air-spaces located in-between cells (Bach, 2012). The textural characteristics of root crops are determined by the constituents of cell wall polymers and cell turgor pressure (Bach, 2012). Root crops consist mostly of thin-walled functional storage cellular tissues and cell walls that comprise of 90% polysaccharides (usually cellulose, peptic substances and hemicellulose) and 10% glycosylated proteins and phenolic constituents (Smith et al., 2003; Bach, 2012). In addition, other components such as, size and magnitude of food particles, level of heterogeneity, and the association of starch with lipids, protein and fiber would modify the characteristics that arise due to the thermal treatment (Trancoso-Reyes et al. 2016).

Cultivar

All purple (purple fleshed) sweetpotato differed significantly from other cultivars with the highest value of hardness, cohesiveness, gumminess and chewiness (Table 4). Beauregard held the highest value for springiness; however, it showed no significant differences from the Golden Nugget and All Purple cultivar (Table 4). Beauregard also was the cultivar with the most resilient texture and the least springy of all cultivars although its resilience and springy texture profile, did not vary significantly from most of the other cultivars. Ginseng produced significantly lower resilience than all the other cultivars tested. Ginseng also produced the lowest parameters for hardness, springiness, gumminess and chewiness however it did not vary significantly from many of the other cultivars. Cohesiveness, gumminess and chewiness were highest in the baked treatments while hardness and resilience were observed to be highest in the open cooked treatments (Table 4). Hardness, gumminess, chewiness and resilience were found to be reduced significantly in pressure cooked sweetpotatoes when compared to the rest of the cooking methods. Cohesiveness had the lowest values among the open cooked treated sweetpotato cultivars. Springiness had no significant effect on pressure cooked treatment sweetpotato roots. Leksrisompong et al. (2012) likewise assessed the impact of sweet potato of various flesh colors on buyer preference and discovered that the orange fleshed sweet potatoes were appeared to be moister and softer than those of other flesh colors (Leksrisompong et al. 2012). The purple shaded sweet potatoes were believed to be stringier and firmer in texture (Leksrisompong et al. 2012). Consumers generally were open to try sweetpotatoes of different flesh colors only if the flavor and textural traits were likewise very much enjoyed (Leksrisompong et al. 2012).

Dry matter content has been reported to be connected to some degree with the texture of potatoes, although this reality is not really clear (Van Marle et al. 1997). The dry weight of potatoes determines the texture of cooked and raw potatoes (Thybo & Martens 1999; Van Dijk et al. 2002; Seefeldt et al. 2011). Previous research studies have shown that, raw potatoes with lower dry matter content are soft, and potatoes with higher dry weight basis are firmer and harder (Gilsenan et al. 2010). Kruger et al. (1998) reported that the dry matter content of the white-fleshed sweetpotato at 18.2% was lower than that of the orange fleshed sweetpotato at 20%. Leighton et al. (2010) in addition observed that the white-fleshed sweetpotato had a moister appearance, a moister texture when first chewed and seemed to have reduced firmness than of orange-fleshed sweetpotato. Leighton et al. (2010), explained that the higher dry matter content of orange fleshed sweetpotato could have added to its being less moist on appearance, more denser and pastier than the white-fleshed sweetpotato. In addition, somewhat lesser dry matter of white-fleshed sweetpotato could account for the higher watery appearance (moisture content) of the cooked white-fleshed sweetpotato when assessed using a trained sensory panel (Leighton et al. 2010). Tomlins and others (2004) reported that the most essential sensory descriptors affecting consumer acceptability were starch and stickiness as they were more favored by consumers compared to the least preferred types were neither starchy nor were they sticky (Tomlins et al. 2004). Nevertheless, Afuape et al. (2014) conducted sensory assessments of fourteen sweet potato cultivars with various flesh colors and discovered that all were acceptable to consumers. Consumer acceptance of flesh color, texture and aroma of boiled sweetpotatoes was significant (Afuape et al. 2014).

Table 1. Physical properties of sweetpotato cultivars (Average sizes-weight, length and diameter, of U.S. no 1 petite size sweetpotato roots cultivated in the 2016 growing season)

Cultivars	Flesh color	Weight (oz)		Diameter (in)		Length (in)	
		Value	Rank	Value	Rank	Value	Rank
All Purple	Purple	6.7 a	1	1.88 a	6	5.34 a	3
Beauregard	Orange	5.9 a	4	1.97 a	4	5.37 a	2
Burgundy	Orange	6.3 a	3	2.11 a	1	5.72 a	1
Carolina Ruby	Orange	6.5 a	2	2.05 a	3	5.14 a	4
Ginseng	Orange	5.2 a	5	1.97 a	5	4.63 a	6
Golden Nugget	Orange	5.2 a	6	2.08 a	2	5.08 a	5

* Values followed by different letters differ significantly at $p<0.05$ by LSD.

Table 2. ANOVA results indicating effect of cultivar on U.S. no 1 petite sweetpotato root size

	Sources	Degree of Freedom	F-Value	P-Value
Weight	Model	23	1.43	0.1596
	Cultivar	5	1.12	0.3656
Length	Model	23	1.12	0.3688
	Cultivar	5	0.49	0.7834
Diameter	Model	23	0.85	0.6513
	Cultivar	5	0.54	0.7454

Table 3. Cultivar and cooking method interaction: Instrumental texture parameters

	Hardness (N)	Rank	Springiness (%)	Rank	Cohesiveness (%)	Rank	Gumminess	Rank	Chewiness	Rank	Resilience (%)	Rank
Cultivars	**Open cooking**											
All Purple	475.55 a*	1	0.60 bcde	8	0.113 ab	3	54.72 a	1	33.31 ab	2	0.08 ab	4
Beauregard	209.51 cd	5	0.72 abc	3	0.086 cdef	10	21.28 bc	5	14.55 cd	4	0.11 a	1
Burgundy	242.02 c	4	0.65 abcd	5	0.086 cdef	9	21.35 b	4	13.80 de	5	0.10 ab	3
Carolina Ruby	140.68 def	8	0.66 bcde	9	0.07 fg	16	9.46 bcd	9	5.95 def	9	0.04 c	7
Ginseng	170.39 cd	6	0.53 cde	13	0.07 fg	17	13.1 bcd	6	7.56 def	8	0.03 c	8
Golden Nugget	61.24 efgh	12	0.48 de	15	0.06 g	18	3.78 d	14	1.85 def	14	0.02 c	18
	Pressure cooking											
All Purple	143.20 de	7	0.60 bcde	7	0.09 bcdef	7	13.00 bcd	8	7.79 def	6	0.02 c	17
Beauregard	122.02 def	9	0.81 a	1	0.08 efg	13	9.48 bcd	9	7.74 def	7	0.02 c	16
Burgundy	51.18 fgh	13	0.58 cde	10	0.103 abcde	6	5.27 bcd	11	3.07 def	12	0.02 c	14
Carolina Ruby	35.79 gh	15	0.45 e	18	0.08 efg	14	2.83 d	15	1.31 ef	16	0.02 c	12
Ginseng	47.62 gh	14	0.57 cde	11	0.106 abcd	5	5.07 cd	12	2.92 def	14	0.02 c	13
Golden Nugget	64.24 efgh	11	0.64 abcde	6	0.076 fg	15	4.66 d	13	3.04 def	13	0.03 c	9
	Baking											
All Purple	333.14 b	3	0.69 abc	4	0.12 a	1	38.83 a	3	26.91 bc	3	0.04 c	6
Beauregard	31.15 h	16	0.45 de	17	0.08 efg	12	2.47 d	16	1.11 ef	16	0.02 c	15
Burgundy	23.43 h	18	0.45 de	16	0.083 defg	11	1.96 d	18	0.89 f	18	0.02 c	10
Carolina Ruby	78.20 efgh	10	0.55 cde	12	0.11 abc	3	8.61 bcd	10	4.76 def	10	0.08 b	5
Ginseng	24.76 h	17	0.49 de	14	0.086 cdef	8	2.06 d	17	1.04 f	17	0.02 c	11
Golden Nugget	426.77 a	2	0.79 ab	2	0.12 a	2	54.71 a	2	45.39 a	1	0.10 ab	2

* Values followed by different letters differ significantly at p<0.05 by LSD

Table 4. Main effect of cultivars on TPA parameters

Parameters	Cultivars					
	All Purple	Beauregard	Burgundy	Carolina Ruby	Ginseng	Golden Nugget
Hardness, (N)	317.30 a	120.89 c	105.54 c	84.89 c	80.92 c	184.08 b
Springiness (%)	0.63 ab	0.66 a	0.56 bc	0.53 c	0.53 c	0.63 ab
Cohesiveness (%)	0.107 a	0.082 b	0.091 b	0.086 b	0.087 b	0.085 b
Gumminess	35.52 a	11.07 c	9.53 c	6.97 c	6.74 c	21.05 b
Chewiness	22.67 a	7.80 c	5.92 c	4.01 c	3.84 c	16.76 b
Resilience (%)	0.05 a	0.05 a	0.05 a	0.04 a	0.02 b	0.05 a

* Values followed by different letters differ significantly at p<0.05 by LSD.

Comparison

In general, the ANOVA result of the six texture parameters evaluated were significant for the cultivar, cooking method and cultivar by cooking method interaction effect, the only exception was the effect of the cooking method on springiness was not significant (Table 5). On the properties of Jewel sweetpotatoes that had been baked partially and chilled before final cooking (Truong & Walter 1994), springiness had no significant effect on pressure cooked treatment sweetpotato roots. Of all the treatments tested, open cooked cultivars of All Purple were the hardest, with no significant variation from the baked Golden Nugget cultivars (Table 5). TPA hardness and fracturability showed comparative patterns and were highly correlated with peak force (Truong et al. 1998). It is noteworthy that the strength of the cell wall and cell tugor pressure are the reason for hardness in plant tissue (Lin & Pitt, 1986). When heat is applied however, the cell membrane structure is disturbed, and there is loss turgor pressure wherein water filters from the cells (Bach, 2012).

First the cell tissues loose solidness quickly, a turgor pressure diminishes (Greve et al. 1994b) then the cell wall loses its integrity as a result of a loss of pectic compounds (Greve et al. 1994a). Starch granules in root crops are available in undefined and crystal-like structures (Bach 2012). The starch in freshly harvested roots range from 6.9% to 30.7% (Tian et al. 1991). In addition, Bach (2012) discovered beetroots are more thermally stable when its texture was compared with that of Jerusalem artichoke tubers and softening of beetroots through boiling was just as a result of break of cell wall structure and loss of turgor pressure. As beetroots have considerable measures of ferulic acid dimers, which are engaged with cross-connecting of pectic polysaccharides between cells, prompting a solid cell adhesion even after after treatment (Waldron et al. 1997a)

Open cooked

All Purple sweetpotato cultivar were the gummiest although they did not vary significantly from baked All Purple and baked Golden Nugget sweetpotato cultivars (Table 5). Baked Golden Nugget sweetpotatoes were also the chewiest, however they did not vary significantly from open cooked All Purple sweetpotato (Table 5). During the chewing process, the cell wall experiences twisting or breaking based on the characteristics the cell wall (Waldron et al. 1997b). Beauregard sweetpotato prepared by open cooking had the highest resilience but its resilience value did not vary significantly from those in baked Golden Nugget sweetpotato and in the open cooked Burgundy and All Purple sweetpotato cultivars (Table 5). The most cohesive were the Beauregard sweetpotatoes to which pressure cooking was applied while the springiest were the baked All Purple sweetpotatoes, although both did not vary significantly from many of the other sweetpotato cultivars tested.

The softest sweetpotato was the Burgundy cultivar prepared by baking, it however did not vary significantly from many of the other cultivars across the various treatments tested (Table 5). The Burgundy sweetpotato to which the baking treatment was applied had the lowest value for both gumminess and chewiness, however not significantly different from most of the other cultivar and treatments (Table 5). Alternatively, an examination by Truong & Walter (1994), the typical texture profile analysis (TPA) curve for baked sweetpotato roots (Jewel cultivar) at 25˚C and 60˚C demonstrated a lower adhesiveness, cohesiveness and springiness. The TPA curve at the primary pressure cycle had a fracture peak, showing that the prepared sweetpotato had a level of firmness (Truong &Walter, 1994). This sort of TPA profile has been reported in cooked tubers of different Irish potato varieties (Leung et al. 1983). The Golden Nugget sweetpotato cultivar, treated with open cooking was the least cohesive and also the least resilient, though not significantly different from most of the other cultivars of same parameter across treatments (Table 5). Taherian & Ramaswam (2009) saw in their experiment that during boiling, take-up or adsorption of water lessen the cohesiveness and weakens the cell walls. Other than this, pectic polymers that play a part in cell adherence are broken down by β-elimination at higher temperatures (Keijbets & Pilnik, 1974; Ng & Waldron, 1997), and divalent cations, particularly Ca2+ and Mg2+ can decrease softening during heating, as the particles cross-interface the pectic polysaccharides associated with the cell adhesion (Favaro et al. 2008). The conduct of the above parameters is related to the sample properties and composition and essentially to the concentration of starch (Trancoso-Reyes et al. 2016). On heating, the crystalline areas are disturbed, water is taken up and the starch forms a gel (Adams, 2004). The gelatinised starch in the case of potatoes can at times occupy the whole cell, in which case the potato will be viewed as soft (Adams, 2004). The least springy cultivar was the pressure cooked treated Carolina Ruby cultivar, however its low springiness value was also not significantly different from that of many of the other sweetpotato cultivars across the various treatments (Table 5). In an investigation by Leighton et al. (2010) five sweetpotato cultivars it was discovered that sweet potatoes expanded in weight after cooking, though no noteworthy contrasts were found for the measure of weight increase between the diverse cultivars. The expansion in weight could be because of the application of moist heat cooking technique, and that the water content in the sweet potatoes increased (being starch based) amid the cooking time frame (Leighton et al. 2010). Fluctuating levels of firmness that emerge from various cooking treatment could be the motivation to measure the differences among varying cooking methods, for example, 29% diminishing in hardness for sous-vide treated samples, 44% for pressure cooked and 96% for cooked specimens when compared with raw samples (Bernad, 2013). Boiling at high temperatures disturbs cell cohesion and adhesion, bringing about a diminish in tissue rigidity (Truong et al. 1998). Asides from this, potatoes with greater dry matter content are softer in texture after they are boiled (Thybo & Martens, 2000; Kaur et al. 2002; Ukpabi et al. 2011). An investigation by Truong et al. (1998) revealed that sweetpotato samples immersed in boiling water were softer than the raw sweetpotato as shown by a less steep bend with reduced fracture strength. In a different report by Leighton et al. (2010) decrease in both shear strain and stress was seen in every single cultivar prepared with steaming technique in contrast to the qualities observed for raw sweet potatoes. The possible reason could be because of the extent in which starch and cell wall constituents break down during cooking, which then impacts on various textural properties among sweet potato cultivars (Leighton et al. 2010). Consequently, the estimation of pressure or shear constraint of raw samples may not be an exact forecast of the textural qualities of sweet potatoes (Truong et al. 1997). Wang et al. (2012) compared sweetpotatoes cooked by high steaming, and those broiled for 40 minutes, and discovered that the level of gelatinization could reach as high as 95% with just 140˚C superheated steam, while cooking in an oven or open fire requires temperatures up to 240˚C. It was likewise found that in spite of the fact that the presence of sweetpotatoes cooked utilizing superheated steam were not burned like the broiled ones, notwithstanding, sweetpotatoes baked at 240˚C for a 1h had the highest sensory score (Wang et al. 2012). The structure of starch granules are a major determinant of textural traits in tuber and root crops (Charoenkul et al. 2011). Starch consists of “amylose (a spiral polymer made up of D-glucose units) and amylopectin (a soluble polysaccharide and highly branched polymer of glucose found in plants)” (Anderson & Gugerty, 2015). The proportion of amylopectin and amylose in starch may thus account for the texture attributes in food products, including, stickiness, resistance against shear stress, swelling of starch granules due to heat, solubility, tackiness, stability of gel, cold swelling, and retrogradation (Satin, 1998).

Correlation

The ANOVA table for analyzing the correlation coefficients for the texture variables showed that the model was significant at p<0.05 (Table 6). The correlation coefficients exhibited a positive relationship between the texture variables springiness, gumminess, chewiness, resilience and hardness of the sweetpotato roots (Table 6). Springiness and resilience were not correlated with cohesiveness and with each other. Gumminess was significantly correlated with hardness and chewiness suggesting they have a relationship. Texture profile examination through instrumental texture estimations that identify with human discernment, are both imitative and empirical in nature (Bhattiprolu, 2004). Imitative tests (mimic gnawing and biting) include instrumental reproduction of conditions under which sensory properties of the specimen are surveyed by people (Bhattiprolu, 2004). Therefore, the imitative test ought to have the most reliable connection with sensory assessment (Szczesniak, 1963). The imitative test produces results for a number of instrumental parameters e.g., hardness, springiness, chewiness and so on, not at all like experimental, which measures just a single parameter. Although, texture standouts amongst the most essential quality traits of root crops, it has been described as one of the most difficult attributes to gauge instrumentally (Bach, 2012). Nevertheless, Bach (2012) in his study, did not find any direct association between the instrumentally measured texture and the sensory assessed texture properties in Jerusalem artichoke tubers. A study by Ellong et al. (2014) reported that the CAM/11/007 cultivar was beneficial for use as an edible vegetable because of its little size, uniformity in color, extraordinary flavor and texture. Although, its sporadic shape and low dietary potential can be a drawback.

Table 5. ANOVA results showing effects of cultivar, cooking methods and their interactions on instrumental texture parameters.

	Sources	Degree of Freedom	F-Value	P-Value
Hardness	Model	17	66.40	<0.0001
	Cultivar	5	84.36	<0.0001
	Cooking method	2	100.00	<0.0001
	Cultivar * Cooking method	10	50.60	<0.0001
Springiness	Model	17	8.47	< 0.0001
	Cultivar	5	6.82	0.0001
	Cooking method	2	1.29	0.2880[NS a]
	Cultivar * Cooking method	10	10.73	< 0.0001
Cohesiveness	Model	17	13.68	< 0.0001
	Cultivar	5	10.57	< 0.0001
	Cooking method	2	22.92	< 0.0001
	Cultivar * Cooking method	10	13.38	< 0.0001
Gumminess	Model	17	31.35	< 0.0001
	Cultivar	5	40.80	<0.0001
	Cooking method	2	35.23	<0.0001
	Cultivar * Cooking method	10	25.85	< 0.0001
Chewiness	Model	17	27.70	< 0.0001
	Cultivar	5	31.46	<0.0001
	Cooking method	2	26.90	<0.0001
	Cultivar * Cooking method	10	25.98	< 0.0001
Resilience	Model	17	33.44	< 0.0001
	Cultivar	5	7.83	<0.0001
	Cooking method	2	80.58	<0.0001
	Cultivar * Cooking method	10	36.81	< 0.0001

[a] NS- not significant

Table 6. Correlation coefficients of TPA parameters

Variable	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience	Hardness
Springiness	1.0					
Cohesiveness	0.38	1.0				
Gumminess	0.52	0.66	1.0			
Chewiness	0.59	0.66	0.98*	1.0		
Resilience	0.43	0.41	0.65	0.64	1.0	
Hardness	0.54	0.56	0.98*	0.95*	0.67	1.0

* Values are significant at p<0.05 by LSD

Conclusion

The results indicated the following conclusions 1. The texture profile analysis (TPA) clearly indicated the quality of organic sweetpotatoes is affected by different processing methods. 2. The mouthfeel characteristics like hardness, springiness, cohesiveness, gumminess and chewiness can be predicted by using instruments like texture analyzer. 3. Gumminess was significantly correlated with hardness and chewiness suggesting they have a relationship. 4. All purple was found to be the hardest, most cohesive, gummy and chewy sweetpotato. The least resilient cultivar, Ginseng, was the also the least hard, gummy and chewy cultivar. Beauregard was the springiest and most resilient cultivar. 5. The different processing conditions like open cooking, pressure cooking and baking affect the textual parameters differently depending upon the conditions. 6. Cohesiveness, gumminess and chewiness was highest under baking conditions. Hardness and resilience was greatest in open cooked treatments. In pressure cooked sweetpotatoes however, hardness, gumminess, chewiness and resilience were found to be reduced significantly when compared to the rest of the cooking methods. Cohesiveness had the lowest values among the open cooked treated sweetpotato cultivars. 7. In general, the hardness and other parameters reduced with processing, but the extent of decrease differed with the variety. 8. Across the treatments, open cooked, All Purple was found to be the hardest, springiest and gummiest cultivar while the baked burgundy sweetpotato were the softest, least gummy and chewy. Open cooked Beauregard were the most resilient while Beauregard prepared by pressure cooking were the most cohesive of all cultivars. Baked Golden Nugget were the chewiest while the least resilient and least cohesive cultivars were the open cooked Golden Nugget. Pressure cooked Carolina Ruby cultivars were the least springy. Results of this study indicate that the prediction of mouthfeel characteristics using instruments will reduce the time and energy to conduct sensory evaluations and helps to assess sweetpotato quality, thus setting bench marks for marketability.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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Research Article

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The determination of gibberellic acid effects on seed germination of *Echinacea purpurea* (L.) Moench under salt stress

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Abstract

The research was conducted to determine the effect of gibberellic acid pre-treatments on germination of *Echinacea purpurea* seeds under salt stress. In the study, three different gibberellic acid concentrations (0, 100, 200 and 300 ppm) were pre-treated. Seeds planted in petri dishes were left to germinate after salt applications at 0, 50 and 100 mM (NaCl) concentrations. Responses of *echinacea* to priming and salt stress treatments were observed on the bases of some growth and viability (radicle and hypocotyl length, radicle fresh and dry weight, hypocotyl fresh and dry weight, germination power, germination speed, mean germination time, germination and sensitivity index) parameters.

According to the result of the research; when the salt concentrations increase, the germination and growth parameters of *echinacea* seeds were inhibited. It was conducted determined that increasing doses of gibberellic acid pre-treatments had significant and positive effects on the germination and growth parameters of *echinacea* seeds under salt stress conditions. In physiological enhancement of echinacea seeds, the best results were obtained from the 300 ppm GA_3+0 mM (control) salt combination.

Keywords: Gibberellic acid, Salt, Echinacea (*Echinacea purpurea* L.), Germination

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Introduction

Echinacea which is a medicinal and aromatic plant, has been used for traditional medicine because of its pharmacological properties in many countries. The first reports of the use of the plants belonging to *Echinacea* genus date to the beginning of the twentieth century, in the Ethnobotanical studies made by WHO, documented uses as a primitive antibioticits use against snakebites to heal wounds (Anonymus, 1999). Although medicinal plants have been used for thousands of years in every culture of the world, serious scientific researches supporting their therapeutic value have begun around 1960 (Lopez and Shepard, 2007). *Echinacea* is an indigenous herbal plant genus of North America and occupies an important place among medicinal plants due to its immunostimulatory properties against respiratory ailments. The genus *Echinacea* is one of the prominent genera of the plants that are utilized in medicinal preparations and drugs (Ahmad et al., 2017). Echinacea plant which is perennials has 9 species. Being commonly used in traditional medicine, E. purpurea, E. pallida and E. angustifolia have been the most investigated of these species (Ivanova et al., 2014). Echinacea which belongs to the family *Asteraceae (Compositae*) is a plant commonly found in the world. *Echinacea purpurea* (L.) Moench has been traditionally also used for the treatment of toothache, snake bite, bowel pain, skin disorders, chronic arthritis, seizure and cancer (Grimm and Muller, 1999). Salinity is considered to be one of the environmental stresses that reduce the growth and efficiency of most glycophytic plants worldwide. Induces both osmotic and ionic stresses leading to deterioration of many physiological and biochemical processes including salinity, water relations, ionic homeostasis, gas exchange and mineral nutrition (Parida and Das, 2005; Munns and Tester, 2008). Gibberellins are involved in the stimulation of enzymes involved in seed germination.

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Gibberellic acid (GA_3) is one of the hormones proposed to control primary dormancy by inducing germination. Cavusoglu et al. (2007) reported that GA_3 was the most effective salt stress reducing agent among plant growth regulators used in the research.

This study was carried out to detect the effects of salt doses with pre-applications in various levels of Gibberellic acid (GA_3) on germination of *Echinacea purpurea* L. seeds.

Materials and Methods

In order to evaluate the effect of seed priming on the germination and seedlings' growth traits of *Echinacea purpurea* L. under different salinity stress levels, a factorial experiment was conducted in completely randomized design (CRD) with four replications, at the laboratory of Seed Science and Techonology in the Department of Field Crops, Faculty of Agriculture, Van Yuzuncu Yil University, Turkey in 2018. Three salt levels (0, 50, 100 NaCl mM) and four gibberellic acid (GA_3) levels (0, 100, 200 and 300 ppm) were used in the experiments. Seeds were rinsed with water and distilled water, then their surface sterilized in 20% sodium hypochlorite (vol/vol) for 5 minutes, followed by 70% alcohol (vol/vol) treatment for 1 minutes, after then, were thoroughly rinsed with sterile deionized water before priming.

The seed lots were imbibed within different doses gibberellic acid (GA_3) in priming treatments. Treated seed lots with GA_3 were kept in darkness in an incubator at 25 ± 0.5 °C for 24 h. Seeds, removed from the solutions (GA_3) were air dried for 24 hours at 25 °C to reach the original moisture content (12-13 %) and then proceed for germination test as suggested by ISTA. Unprimed seeds were used as control. Treated seeds were placed in 9 cm diameter sterile petri dishes with filter paper and 20 seeds were placed in each petri dish and 5ml of salt solution was added dish to all petri except for control treatments, to the control treatments was given distilled water (5 ml), then petri dishes were placed in a totally dark incubator which stable at temperature (25±0.5ºC). As a final step, after 14 days all parameters were observed, measured and recorded. The root and shoot vigors were calculated as the sum of total root length (cm) and shoot length (cm) of all the seedlings of a replicate divided by the number of seedlings. Fresh root and shoot were then placed in a hot air oven (70 ^{0}C for 24 hours) to dry (Anonymus, 2012). Root and shoot dry masses were weighed germination rate, germination power, germination index, mean germination time and sensitivity index were calculated with the following formulas. It was considered that number of germinated seeds on 7th day as "germination rate" and number of germinated seeds on 14th day as "germination power". Germination rate (GR) was calculated using the Equation 1 (Akinci and Caliskan, 2010).

GR = Total seeds germinated after day 14/Total number of planted seeds (Equation 1)

Germination index (GI) was calculated using the Equation 2 (Wang et al., 2004).

$GI=\Sigma(Gi/Tt)$ (Equation 2)

GI: Germination index; Gi: i. Days germinated seed rate; Tt: count day

Mean germination time (MGT) was calculated using the Equation 3 (Ellis and Roberts, 1980).

$MGT=\Sigma(fx)/\Sigma f$ (Equation 3)

f: Number of seeds germinated x: germination day

Sensivity index (SI) was calculated using the Equation 4 (Foolad and Lin, 1997).

SI= MGT in the salt application/ MGT in the control application (Equation 4)

Data were analyzed statistically by using analysis of variance with COSTAT (version 6.3) software. The variance analysis of data was performed (ANOVA) and the multiple comparison of the means was made according to the Duncan test (Duzgunes et al., 1987).

Results and Discussion

According to the research results, salinity and seed priming showed a significant effect on all parameters. Only, the effect of gibberellic acid on the radicula length wasn't found insignificant. Furthermore, salinity stress x seed priming interaction that it was was found important with regard to parameters such as dry radicula weight (mg) and sensitivity index (%). Salinity stress x seed priming Interaction in terms of dry radicula weight seem seeds primed with GA_3 unlike untreated seeds had the highest germination value at all salinity levels. While the highest sensitivity index was obtained as 1.54 % from seeds primed with 100 ppm GA_3, in 100 mM salt stress conditions, the highest dry radicula weight was reported as 5.70 mg from seeds primed with 300 ppm GA_3 in non-stress (0 mM NaCl) conditions.

Highest germination power, germination rate and germination index were determined as 92.50, 66.25 and 14.64 % from 0 mM (control) salt treatments, also the lowest values were as obtained as 72.08, 13.75 and 8.56 % from 100 mM NaCl applications. In addition, the effect of gibberellic acid on the germination rate was found significant and the best mean (47.77 %) was determined from 300 ppm GA_3, lowest germination rate (33.88 %) is due to control of GA_3. But, among the first three doses of gibberellic acid there isn't any a different as statistically. Based on statistical analysis, salinity significantly decreased mean germination time of seeds primed with 200 and 300 ppm GA_3 applications. In salt doses of 50 mM and 100 mM, the applications of gibberellic acid in concentrations of 100, 200 and 300 ppm caused to the increase in germination power or rate, respectively. In the result of this research, mean germination time (6.37 day) has shortened with control (0 mM) salt application. The longest average germination time recorded as 9.57 day from 100 mM NaCl treatments. As for the sensitivity index, increasing salt applications have also increased these values. Sensitivity index value is 1.46 % in 100 mM salt dose and 0.46 % in 0 mM salt dose. In this study, we observed that germination percentage delayed and decreased with increasing NaCl concentration and drastically reduced at 100 mM NaCl. The results showed that echinacea is highly sensitive to salinity in the germination stage. In carried previous work by Yuonesi and Moradi (2015), reported that is consistent with the hypothesis that under salinity stress, priming can prepare a suitable metabolic reaction in seeds and can improve seed germination performance and seedling establishment. These results agree with Singh and Jakar (2018), in *Vigna mungo* and Fardus et al. (2018) in wheat, they suggested that salinity may influence germination by decreasing the water uptake, and germination percentage declined with increase of salinity level. However, osmotic stresses reduce germination percentage (Cornelia and Bandici 2008; Maghsoudi and Arvin 2010) although, the seeds pre-treated with GA_3 solutions exhibited higher germination percentage. Sabra et al. (2012) reported that photosynthetic activity in echinacea was affected by salinity and Zollinger et al. (2007) also found a similar reduction in photosynthetic rate and stomatal conductance in *E. purpurea* irrigated with increasing concentrations of salinity. In addition, Sanam et al. (2014), different levels of salinity significantly reduced germination rate, germination vigor and index. The results also showed that by increasing salinity levels, the percentage of germination and normal seedlings significantly decreased and the mean time to germination increased, compared to the control treatment. But the seeds treated with GA_3 showed higher viability and better performance under salinity stress condition. Ali et al. (2012) and Zadeh et al. (2015) reported that application of GA_3 enhanced growth parameters (shoot length, shoot fresh weight, shoot dry weight, root lenght, root fresh weight, root dry weight, leaf area etc.) under saline condition. These results are consistent with those of Jamil and Rha (2007) in sugar beet, Erdemli and Kaya (2015) in sunflower, Yıldız et al. (2017) in sweet william, Cavusoglu et al. (2007) in radish seed, Singh and Jakar (2018), in *Vigna mungo* and Zadeh et al. (2015) in echinacea. Promotion in seed germination with GA_3 may be due to increased uptake of oxygen and a-amylase activity.

Yalcın (2010) and Yildiz et al. (2017) recorded that the positive and significant effects of GA_3 applications on germination power were found. Jamil and Rha (2007) reported that water uptake of primed seeds also increased significantly with increasing concentration of GA_3 as compared to control. Erdemli and Kaya (2015), recorded that it was concluded that seed treatment with GA_3 can be beneficial for decreasing the effect of abiotic stress conditions on germination. It was seen that as gibberellic acid dose increases germination parameters were improve when compared to control.

Table 1. Effect of gibberellic acid treatments on germination of echinacea seeds under salt stress

Applications		Germination power (%)	Germination rate (%)	Mean germination time (day)	Germination index (%)	Sensitivity index (%)
Salt Doses	GA3					
Control (T0)	GA0 (control)	90.00	68.33	6.50	15.51	-
	GA100	91.66	66.66	6.62	13.39	1.01de
	GA200	95.33	60.00	6.54	14.27	1.00 de
	GA300	95.00	70.00	5.81	15.41	0.89 e
T0 Means		92.5 a	66.25 a	6.37 c	14.64 a	0.72 c
50 mM (T5)	GA0 (control)	88.33	26.66	8.29	11.78	1.41 ab
	GA100	83.33	40.00	8.05	12.48	1.23 c
	GA200	86.66	41.66	7.28	12.10	1.15 cd
	GA300	88.33	50.00	7.51	13.55	1.15 cd
T5 Means		85.41 a	39.58 b	7.78 b	12.48 b	1.23 b
100 mM (T10)	GA0 (control)	70.00	6.66	9.99	7.60	1.53 a
	GA100	76.66	10.00	10.03	9.93	1.54 a
	GA200	76.66	15.00	9.84	7.81	1.50 a
	GA300	70.00	23.33	8.43	8.91	1.29 bc
T10 Means		72.08 b	13.75 c	9.57 a	8.56 c	1.46 a
GA_3 Doses Means	GA0 (control)	82.77	33.88 b	8.26 a	11.63 ab	0.98 c
	GA100	83.88	38.88 b	8.23 a	11.94 ab	1.26 a
	GA200	82.22	38.88 b	7.89 ab	11.39 b	1.20 ab
	GA300	84.44	47.77 a	7.25 b	12.62 a	1.11 b
CV (%)		10.28	19.39	8.37	9.76	11.20

*There is no significant difference between the means indicated with same letter (5%).

Table 2. Effect of gibberellic acid treatments on some characteristics of echinacea seedlings

Applications		Radicula lenght (cm)	Plumula lenght (cm)	Fresh radicula weight (mg)	Fresh plumula weight (mg)	Dry radicula weight (mg)	Dry plumula weight (mg)
Salt Doses	GA3						
Control (T0)	GA0 (control)	1.23	2.65	57.66	374.7	5.20 ab	29.26
	GA100	1.71	3.01	59.43	388.66	5.03 a-d	32.0
	GA200	1.67	3.13	64.66	417.6	5.13a-c	33.66
	GA300	1.63	3.43	63.90	441.23	5.70 a	34.76
T0 Means		1.56 a	3.05 a	61.41 a	405.5 a	5.26 a	32.42 a
50 mM (T5)	GA0 (control)	1.03	1.66	54.53	354.63	4.33 c-f	24.20
	GA100	0.78	2.36	57.26	357.06	4.23 d-f	26.33
	GA200	1.10	2.46	63.86	397.23	4.63 b-e	24.96
	GA300	1.28	2.53	60.23	432.96	4.03 ef	30.30
T5 Means		1.05 b	2.25 b	58.97 a	385.47a	4.30 b	26.45 b
100 mM (T10)	GA0 (control)	0.50	0.91	33.33	165.5	1.63 g	21.76
	GA100	0.46	1.15	39.20	188.80	3.80 f	21.66
	GA200	0.70	1.10	40.66	195.7	3.66 f	23.10
	GA300	0.72	1.48	40.93	224.76	3.73 f	23.70
T10 Means		0.59 c	1.16 c	38.53 b	193.69 b	3.20 c	22.55 c
GA_3 Doses Means	GA0 (control)	0.92 b	1.74 c	48.51 c	298.27 b	3.72 b	25.07 b
	GA100	0.98 ab	2.17 b	51.96 bc	311.51 ab	4.35 a	26.66 ab
	GA200	1.15 ab	2.23 b	56.40 a	336.84 ab	4.47 a	27.24 ab
	GA300	1.21 a	2.48 a	55.02 ab	366.32 a	4.48 a	29.58 a
CV (%)		9.12	11.51	7.98	7.98	8.01	8.20

*There is no significant difference between the means indicated with same letter (5%).

The effect germination inhibiting in seeds of salt has been revealed in many studies. It has been reported that it was caused to the inhibition of water intake of high salt concentration on the decrease of germination rate, toxicity of salt and the can not be activated due to salt stress of required enzymes during germination (Mansour, 1994; Essa, 2002; Sadeghian and Yavari 2004). However, Seyedi et al. (2012) reported that, with increasing salinity stress germination characteristics such as germination percentage, germination rate and seedling fresh weight decreased. All of the early growth parameters have decreased as parallel with salt application.

Priming of seeds with different materials particularly GA_3 was useful for alleviating salt stress effects and improving germination and seedling establishment under salt stress. Under salinity condition, primed seeds possessed more germination and emergence than control. According to the results of the study; the highest values for investigated characters such as radicula and seedling lenght, fresh radicula and seedling weight and dry radicula and seedling weight were determined as 1.56 cm, 3.05 cm, 61.41 mg, 405.5 mg, 5.26 mg and 32.42 mg from control applications (0 mM NaCl), respectively. Also, the most negative results were determined as 0.59 cm, 1.16 cm, 38.53 mg, 193.69 mg, 3.20 mg and 22.55 mg from 100 mM NaCl applications, respectively. In terms of gibberellic acid applications the most positive results for the characters such as radicula and seedling lenght, fresh radicula and seedling weight and dry radicula and seedling weight were obtained from 300 ppm GA_3 applications as 1.21 cm, 2.48 cm, 56.40 mg, 366.32 mg, 4.48 mg and 29.58 mg, respectively In this experiment, we observed that, growth parameters reduced with increasing salinity (Table 2) which was similar with the report of Sabra et. al. (2012) in echinacea species, Nazarian (2016) in rapeseed, Salahuddin et al. (2017), in mungbeen, Fardus et. al. (2018) in wheat and Singh and Jakhar (2018), in *Vigna mungo*.

Conclusions

In the trial conducted to evaluate some germination and growth characteristics (radicle length, shoot length, radicle age and dry weight, shoot age and dry weight, germination strength, germination rate, average germination time, germination and sensitivity index) of echinacea was concluded that germination and growth parameters of echinacea seeds were inhibited as the salt concentration increases. Echinacea seeds exposed to the salt stress and gibberellic acid concentrations were found to have a significant positive effect on germination and growth properties of echinacea.The best results were obtained from the combination of 300 ppm GA_3 and 0 mM (control) salt in the improving as physiological of echinacea seeds. As a result, it was determined that GA3 treatments eliminated the germination-inhibiting effects caused by salt stress and shortened the average germination time.

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Population change and distribution of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) in strawberry greenhouses

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Abstract

Plant protection has an important place among problems related to strawberry cultivation. Red spider mites and thrips are the main pests observed on strawberries, and among these, the most important for Antalya province is *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). This study was performed in 2017 and determined the population change and in-greenhouse distribution of *Frankliniella occidentalis* with direct counts on flowers and blue traps in three strawberry greenhouses in Serik county in Antalya province. The research was completed in three different greenhouses, with 25 blue sticky traps in the 1st greenhouse with 4 da size and the 2nd greenhouse with 3.5 da size and 15 traps in the 3rd greenhouse with 2.5 da size. Traps were collected each week, with the numbers of thrips recorded. On dates when the traps were changed, the thrips found on plants were counted by examining ten flowers on three plants below or close to the blue sticky traps by eye or with a loupe with counts performed until the day of harvest. At the end of the study, the pest population reached a certain level from the start of flowering in November in the three greenhouses, and then fell in the middle of December. From the middle of December, the population began to increase and this increase continued until the strawberries were harvested. The number of pests per trap varied from 0.6 to 1904.2. When the whole production season is considered, the mean pest numbers per trap in the three greenhouses were 287.2, 72.3 and 271.27 thrips/trap. The number of pests per flowerhead varied from 0.0 to 2.5. When the whole production season is considered, the mean numbers of pests per flowerhead in the greenhouses were 0.26, 0.08 and 0.16 thrips/flowerhead. In light of the data obtained in the study, and considering the economic damage threshold value recommended by previous research results, it was concluded there is no need for chemical intervention against *F. occidentalis* in the region.

Keywords: Antalya, Greenhouse, Population change, Western flower thrips

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Introduction

With an important place in the berry fruit group, strawberry (*Fragaria* sp.) (Rosaceae) is cultivated in many parts of the world. The perennial, herbaceous, evergreen strawberry is a plant rich in taste, vitamin and mineral material. It can be found in markets in the months before other fruit species, has very high allure and vitamin C content which has led to this fruit being very popular in markets in some countries and being sold for high prices (Erenoğlu et al., 2000).

In Turkey, strawberry cultivation began in the 1970s and has rapidly increased especially in recent years. Turkey's strawberry production of 353 thousand tons is third place after production from the USA and Mexico (TZOB, 2015).

Strawberry cultivation is found in a large portion of Turkey due to varying climatic and soil characteristics. However, the largest portion of Turkey's strawberry production comprises production from the Mediterranean, Marmara and Aegean Regions. In 2014, Turkish production was led by Mersin with 132,556 tons, following with Aydın at 62,859 tons and Antalya in third place with 56,412 tons, and these provinces were followed by Bursa, Manisa, Konya, Elazığ, and İzmir (TZOB, 2015).

In addition to economic problems in strawberry cultivation, problems related to plant protection have an important place. The main pests for strawberry are red spider mites and thrips with the most important of these in Antalya being *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) (Keçecioğlu and Madanlar, 2002). Known as the Western Flower Thrips (WFT), *F. occidentalis* was first identified in Turkey on vegetables in Antalya in 1993 (Tunç and Göçmen, 1995) and reported a short time later in Çukurova (Atakan et al., 1998), İzmir (Yaşarakıncı and Hıncal, 1997) and the southeast Anatolian region (Göven and Özgür, 1990; Efil et al., 1999; Yıldız and Özpınar 1999).

As intervention against *F. occidentalis* generally involves intense pesticide application, resistance in observed against pesticides, which causes cultivators to use even more pesticides (Immaraju et al., 1992; Brodsgaard,

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1994; Espinosa et al., 2002; Herron and James, 2005; Dağlı and Tunç, 2007; Gao et al., 2012; Dağlı, 2018).

These applications have direct negative effects on beneficial insects and indirectly cause environmental pollution. These problems have led to the necessity to apply integrated and biological intervention methods.

In Turkey, thrips intervention comprises a significant portion of biotechnical intervention methods. Determining the population change and in-greenhouse distribution and assessing the threshold of population density will be beneficial in deciding about interventions. As stated by Binns and Nyrop (1992), deciding is an important aspect of current Integrated Intervention Programs, and will continue to play an important role in maturation of integrated intervention programs in the future. It is important to know the number and distribution of pests in an area when deciding about precautions to take against these pests. This may be determined with a good sampling method.

In this study, population variation and in-greenhouse distribution graphs were created for pests with the aid of blue traps and direct thrips counts on flowers in three strawberry greenhouses in Kadriye neighborhood of Serik county in Antalya province.

Materials and Methods

This study was completed in Kadriye Municipality linked to Serik county in Antalya where strawberry production is intensely practiced. The main materials in the trial were *F. occidentalis* populations, strawberry plants and blue sticky traps.

The study was completed in high tunnel greenhouses with sizes of 2.5, 3.5 and 4 da.

In the trial greenhouses where the research was completed, all processes related to plant cultivation were performed by producers in accordance with regional conditions. Some information related to the trial greenhouses in the study is given in Table 1.

The study was completed in two stages. The first stage used blue sticky traps to count mobile insects. With this method, blue traps were homogeneously hung in the strawberry areas with 25 blue sticky traps each in the 1st greenhouse with 4 da size and the 2nd greenhouse with 3.5 da size and 15 traps in the 3rd greenhouse with 2.5 da size. The traps were placed at 5-meter intervals. The traps were hung at 10-15 cm above the strawberry plants. The trial used the 10 x 25 cm size blue sticky traps obtained from Bioglobal Company. The first traps were hung on 20 November 2016 to monitor the change in pest populations. The labels on the traps had information about the date they were hung, trap number and greenhouse number. Traps were collected every week and thrips numbers were counted. On the dates the traps were changed, ten flowers on three plants immediately below or near the blue sticky traps were investigated by eye and with a loupe. Counts continued until the 25 March 2017.

Table 1. Information about the greenhouses in Kadriye Municipality where the experimens were established

Greenhouse no	Seedling type	Planting date	Beginning of flowering	Uprooting date	Coordinates
1	Frigo seedling	05.10.2016	20.11.2016	20.06.2017	36.8910940, 31.0026100
2	Tubed fresh seedling	29.09.2016	10.11.2016	26.05.2017	36.8912920, 31.0043500
3	Frigo seedling	07.10.2016	20.11.2016	20.06.2017	36.8904620, 31.0081500

Results and Discussion

In line with the Material and Method, the logarithmic graphs of population variation for *F. occidentalis* identified from counts of sticky traps in the greenhouses are given in Figure 1. During the study, a total of 379,208 individual thrips were counted with 376,798 in traps and 2,410 on flowers during the strawberry season.

When Figure 1 is investigated, the population development for *F. occidentalis* in the three greenhouses appears to be similar. Within the greenhouse, in November at the start of flowering a certain pest population level was reached and this level fell until the middle of December. From the middle of December, population increases began and these increases continued until strawberries were harvested. The number of pests per trap varied from 0.6 to 1904.2. Considering the whole production season, the mean number of pests were 287.2, 72.3 and 271.27 thrips/trap in the three greenhouses, respectively.

Data obtained from studies of flowers in parallel to trap studies are given in Figure 2.

When Figure 2 is investigated, there appears to be continuous variation in the pests on flowers. The number of pests per flower head varied from 0.0 to 2.5. When the whole production season is considered, the mean number of pests was 0.26, 0.08 and 0.16 thrips/flower in the three greenhouses, respectively.

Gonzalez Zamora and Garcia Mari (2003) reported the number of pest larvae on flower heads of old and young flowers varied from 2.60 to 3.53 while the number of adults varied from 0.56 to 4.23. Atakan (2008) determined the number of *F. occidentalis* larvae varied from 0.04 to 1.36 per flower head with the number of adults varying from 4.24 to 22.48 in 5 samplings of strawberry flowers in Adana performed in May and June 2008. Yıldırım and Başpınar (2013) in a study of two strawberry greenhouses in Aydın found *F. occidentalis* was the only thrips species and determined the pest began to be observed in the area from the middle of April, reached highest levels in June and population levels began to fall after July. The study reported the thrips count per flower were between 0.0 to 11.33. Atakan et al. (2016) in a study of a strawberry greenhouse in Adana in 2011-2012 identified the thrips larva and adult numbers were 0.0/flower to 5.05 larvae/flower and 11.75 adults/flower in 2011, while in 2012 this varied from 0.0/flower to 2.35 larvae/flower and 13.30 adults/flower.

When this study is compared with literature findings, it it appears to be similar, with the number per flower head found to be lower than maximum pest numbers.

The distribution of *F. occidentalis* linked to trap locations is given separately for each of the three greenhouses in Figure 3.

When Figure 3 is investigated, though the structure and trial patterns in the 1st and 2nd greenhouses were very similar, there were differences observed in both the population density and distribution within the greenhouse of pests. In greenhouse no. 1, a total of 208,207 thrips were caught during the whole experiment in all traps, while this number was 50,590 in greenhouse no. 2. In the 1st greenhouse, the first three places in terms of trapping were traps no. 24, 22 and 4, while in the 2nd greenhouse the first three places went to traps no. 9, 10 and 4. As understood from the trial pattern in Figure 3.3 and 3.4, the first two traps in greenhouse no. 1 were located at the east edge of the greenhouse, while the first two traps in greenhouse no. 2 were located in the northwest of the greenhouse. In both greenhouses, trap no. 4 located at the east edge of the greenhouse attracted the same proportion of pests. In total, 118,001 thrips were caught in greenhouse no. 3, with traps attracting most pests found in the center of the north edge of the greenhouse (Figure 3).

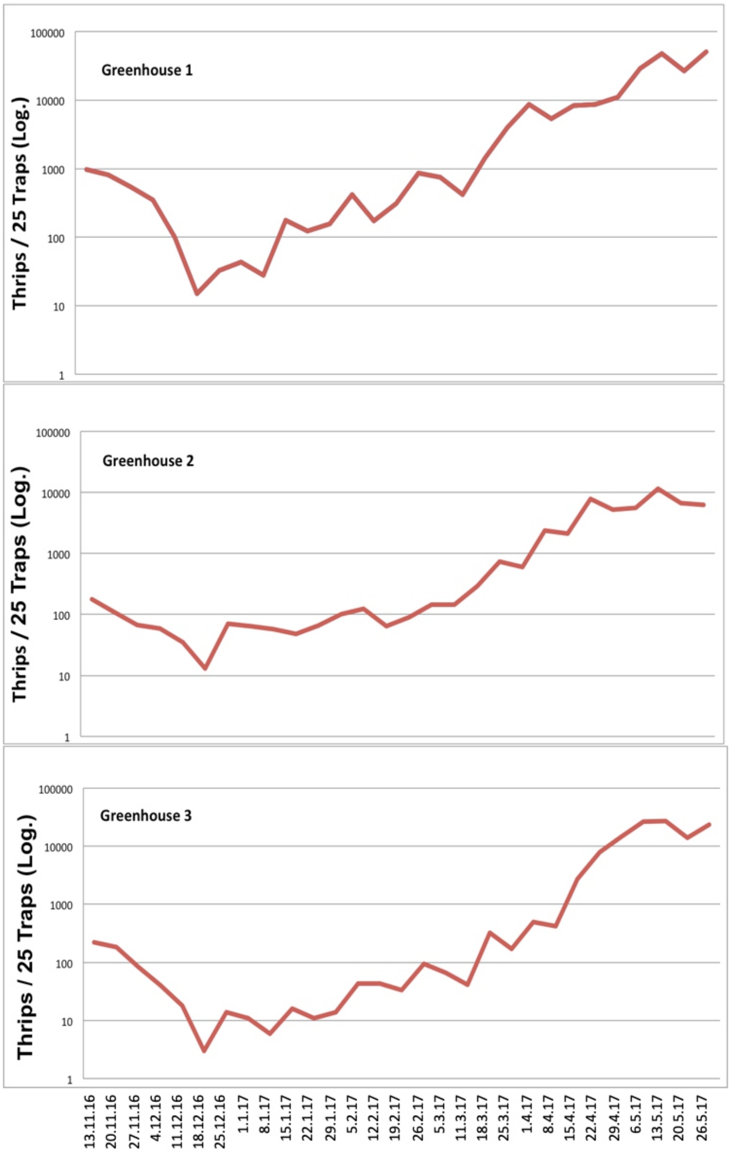

Figure 1. Population development of *Frankliniella occidentalis* in blue sticky traps. Logarithmic data were used in the graphs for the numbers of thrips population.

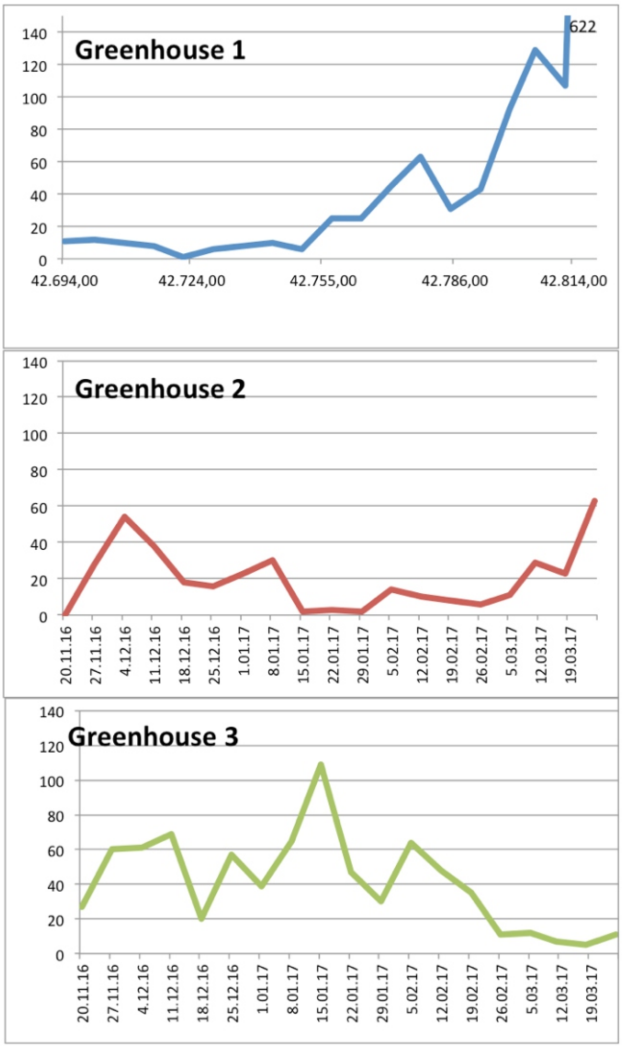

Figure 2. Population development of Frankliniella occidentalis on strawberry flowers

When all greenhouses are considered together by investigating Figure 3, there is no pattern found in terms of pest distribution.

When Figure 3 is investigated, the number of thrips caught in traps in the first greenhouse was least in the central row in east-west direction. In the second greenhouse the traps in the northeast corner and in the southwest corner had least number of thrips identified. In the third greenhouse, all traps found on the east edge of the greenhouse had lowest number to thrips.

In the study, as mentioned above, counts directly on strawberry flowers were completed, with the number of thrips according to location of flowers in the greenhouses given in Figure 4.

When Figure 4 is investigated, the first two greenhouses which resemble each other appear not to show similarities linked to the number of thrips in relation to the location of the flowers. In the first greenhouse, the regions in first place for density were the numbers 6, 3 and 1, while in the second greenhouse, the numbers 1, 2 and 16 were in first place. In the first greenhouse, these regions were two in the southwest of the greenhouse and one in the center of the west edge of the greenhouse. In the second greenhouse, again, the first two regions in terms of density were in the southwest, with the third in the southwest edge of the greenhouse. When the figure is investigated, the thrips population in the first greenhouse clustered in the southwest, while they were distributed mainly along the greenhouse edges in the second greenhouse. In the third greenhouse, the thrips population did not show clear distribution, with population a little higher in the northeast of the greenhouse.

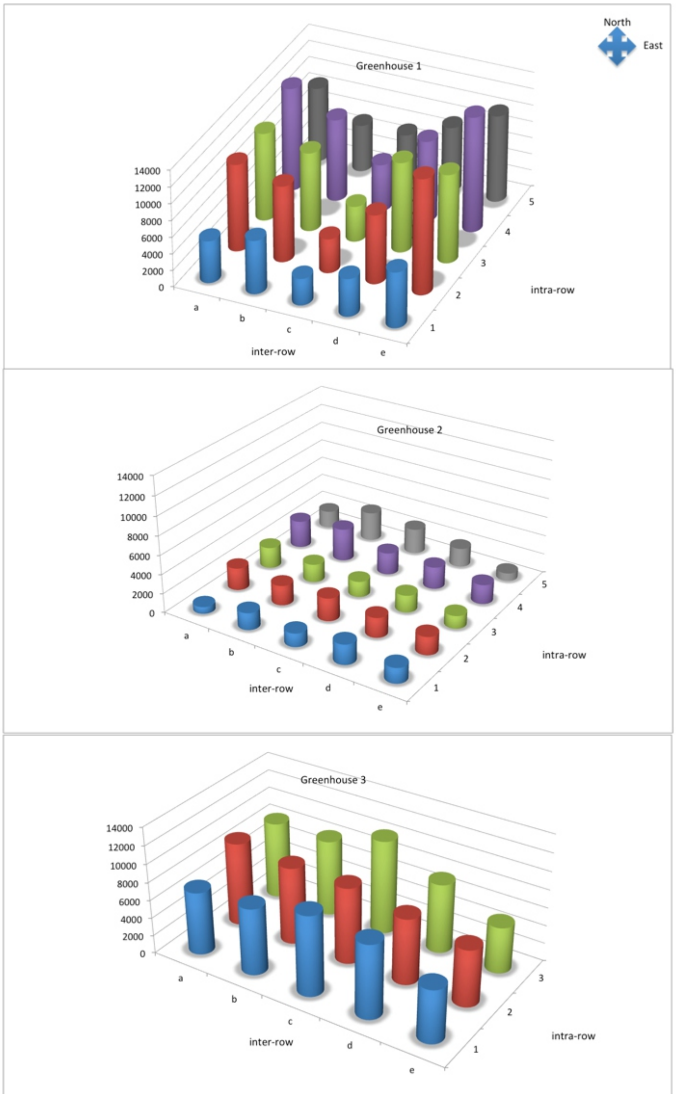

Figure 3. Distribution of *Frankliniella occidentalis* caught in traps within the greenhouses (position of traps shown by a, b, c, d, e length of greenhouse, 1, 2, 3, 4, 5, width of the greenhouse. Trap numbers: a1:1, a2:2, a3:3, a4:4, a5:5, b1:6, b2:7, b3:8, b4:9, b5:10, c1:11, c2:12, c3:13, c4:14, c5:15, d1:16, d2:17, d3:18, d4:19, d5:20, e1:21, e2:22, e3:23, e4:24, e5:25). Cumilative data according to time were used in the graphs for the numbers of thrips population.

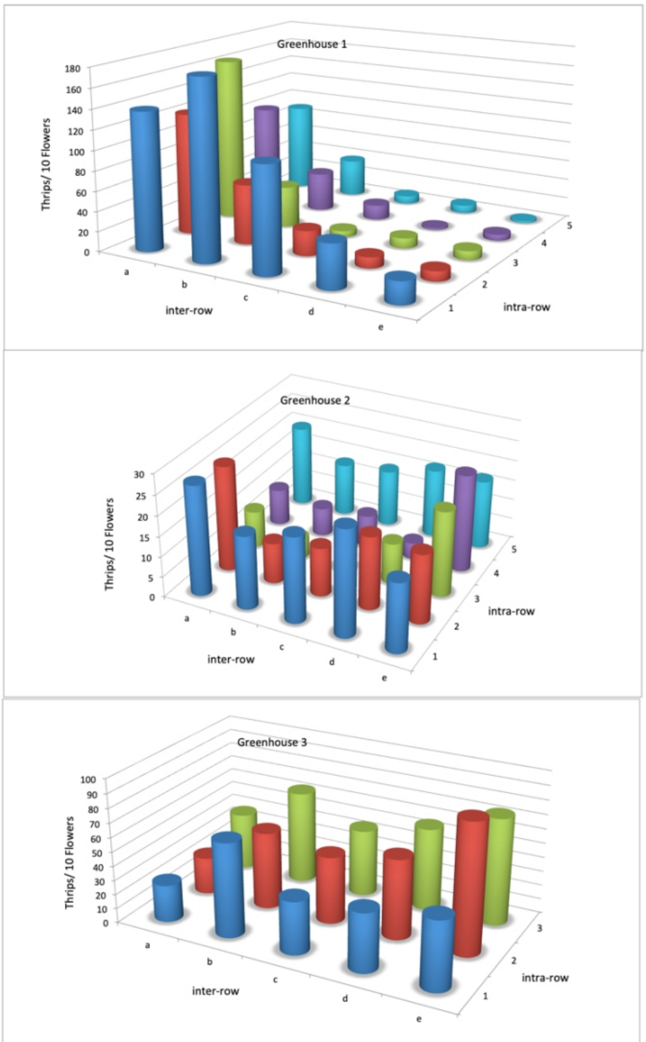

Figure 4. In-greenhouse distribution of thrips populations on flowers according to trap locations. Cumilative data according to time were used in the graphs for the numbers of thrips population.

Steiner and Goodwin (2005a) used yellow sticky traps for weekly counts in strawberry greenhouses and used transformed numbers to identify a low-level correlation between pest numbers on flowers and individuals in traps and emphasized that 20-30 females caught per trap reflected the economic damage threshold. This count was equivalent to 5 adult females per flower head with Steiner and Goodwin (2005b) accepting 5 adult females on flowers as the economic threshold. Grema et al. (1997) reported the number of thrips causing economic harm was 10 individuals per flower, while Coll et al. (2006) gave the economic damage threshold for *F. occidentalis* as 10 individuals/flower and 24 individuals/flower for winter and spring strawberries. Atakan et al. (2016) in a study of strawberries in Adana emphasized that damage was not observed in spite of 10 or more thrips adults per flower on more than 60% of strawberry flowers. Again, the authors in this study proposed that 15 pests per flower head did not cause damage and that the economic damage threshold for these pests needs to be recalculated.

In this study, during 19 weeks, counts determined the maximum thrips numbers per flower head were 2.5 and 0.3 on the 25 March in no. 1 and no. 2 greenhouses, while it was 0.4 on 15 January for no. 3 greenhouse. This study did not observe any signs of harm to fruit caused by thrips.

Conclusion

One of the most important elements in deciding to intervene against pests is knowing the population density of the pests. Sampling methods are important for identification of the population density of pests. One of the factors affecting samples and selection of sampling methods is the reproductive status of pests and distribution of nutritional areas. As stated by Southwood (1976), sampling methods should be designed linked to the insect species and according to the biology and distribution of the insects.

Spending a portion of their lives in the soil and with excessive reproductive ability, *F. occidentalis* was counted using blue sticky traps and directly on flowers in this study in an attempt to determine the status of this pest within the greenhouse.

The results of the study reveal that the pest did not show a certain distribution but spread throughout the greenhouse when both thrips numbers in traps and direct counts on flowers are assessed. As a result, it was concluded that in order to monitor and determine the pest population, random sampling should be made to represent the whole greenhouse rather than oriented sampling.

Additionally, as there was no linear correlation between the individual numbers caught in traps and direct counts on flowers, within the framework of integrated intervention studies, it is considered that direct counts on flowers will be more accurate in deciding on interventions. However, it is recommended that blue sticky traps be used for identification of the time the pest occurs and determination of population changes.

In light of the data obtained in the study, and considering the economic damage threshold values proposed in line with previous research results, the opinion that there is no need for chemical intervention against *F. occidentalis* in the region gained support.

In conclusion, due to different opinions and approaches related to the economic threshold of Western Flower Thrips in studies to date, there is a need for studies to create a more dynamic threshold for the pest based on the reality that this species will give different responses to different ecological factors, as with all pests.

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