Doi: 10.26558/ijcst.373589

IJCST International Journal of Crop Science and Technology
Volume 4, Issue 1 , 2018 ISSN: 2458-7540

Determination of Spatial Variability in Sunflower Production

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Abstract: Aim of this research is to determine spatial variability of soils, nutrients in soil and yield for sunflower production to assess variable rate fertilisation. Materials were sunflower field, and GNSS.. Total size of the research field was 35.8 ha. Soil samples were taken from 0-30 cm and 30-60 cm depths. Soil texture, saturation point (%), pH at saturated soil, Lime (%), total salinity (%), $CaCO_3$, organic matter, useful P (P_2O_5), useful K (K_2O), field capacity (%) and wilting point (%) were determined. Soil texture was found mostly clay but clay loam and a sandy clay loam texture was also determined. Mean values and standard deviations for saturation point 57.35% and 7.44%, pH 7.30 and 0.66, salt 0.07 and 0.01, lime 7.63 and 0.68, organic material 1.29% and 0.17%, P_2O_5 18.22 and 2.52, K_2O 146.05% and 30.82, field capacity 30.34% and 4.07%, and for wilting point 19.18% and 2.72. Mean yield was 2100 kg/ha. Required fertilisers will be 285 kg/ha Ammonium Sulphate (21%N) and 115 kg/ha Calcium Ammonium Nitrate (26%N) for constant rate fertiliser application as conventional application. If this fertiliser is applied as variable rate; amount of fertilisers will be 115 kg/ha Calcium Ammonium Nitrate (26%N) for whole field and 285 kg/ha Ammonium Sulphate (21%N) should be applied for 250 ha. field size. Urea (46%N) suggested as 130 kg/ha for 100 ha. According to the results, fertiliser requirement of the sunflower field is not constant. Fertilisation necessity is spatially determined. Fertiliser application with spatial variable rate will increase yield, quality and decrease fertilisation cost and environmental effects.

Key words: Sunflower, Precision agriculture, Spatial variability, Variable rate fertilisation

INTRODUCTION

Precision farming is environmentally friendly management method for agriculture. It is based on spatial variability of soil, water, and product specifications and to apply agricultural inputs as variable rate. Aim of this research is to determine spatial variability of soils, nutrients in soil and yield for sunflower production to assess variable rate fertilisation possibilities.

Darvish et al. (2015) examined the spatial variability of certain soil variables, e.g.; soil pH, electrical conductivity (ECe), calcium carbonate ($CaCO_3$), organic matter (O.M), % cation exchange capacity (CE), gypsum content and particle size distribution develop maps and assess the spatial correlations among them. Ungor and Akdemir (2010) developed a software to create prescription maps. Ozguven and Turker (2010) worked on comparative analysis of wheat, cotton and corn production. The cost of precision farming can be covered by 16.41% yield increase in wheat production in Central Anatolia, 3.96% yield increase in cotton in Southern Anatolia, and 4.01 yield increase for corn in Combine systems for 100 ha field size in 2008.Tekin and Sindir (2013) developed and tested a centrifugal fertiliser machine control system to realize variable rate controller according to the prescription map. The system can easily adopted local made fertilisers.Topakci et al. (2010) developed a software can determine field efficiency, map files, and prepare documentation for study results. The software were tested for granule fertilization. Results from investigation that was conducted by Ion et al (2015) in Southern Romania were determined fresh and dry aboveground biomass of sunflower

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under different sowing and growing conditions varied from 62.88-81.65 t/ha. and 15.95-19.52 t/ha, respectively. Estrada et al (2010) researched distribution of sunflower biomass and seed yield in saline soil of Mexico highlands, and the greatest dry matter accumulation had been obtained in the stem. Ziebell et al (2013) were determined biomass of main stem unchanged or increased as planting density increased by the results from their research "sunflower as a biofuels crop: An analysis of lignocellulosic chemical properties"

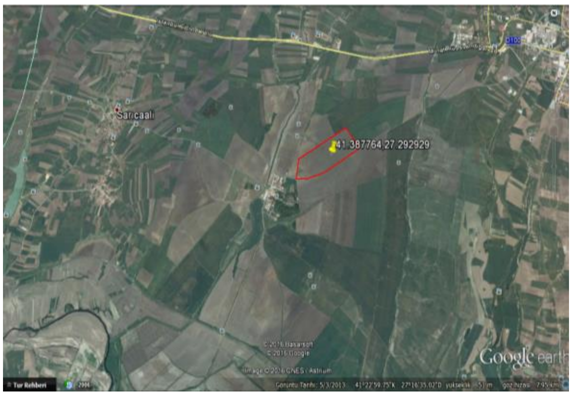

Figure 1. Experimental field in Kırklareli

Objective of the paper is to determine spatial variability of soil and crop specifications for sunflower production. Spatial variability of the analysed parameters were used to determine fertiliser requirement.

MATERIALS AND METHODS

Research crop was sunflower to determine situation of GAP in the practice. Research field area was 38 hectares. It was shown in (Figure 1). Field operations for sunflower production were given in (Table 1).
In addition, general agricultural operations in sunflower were also determined for Thrace Region, Turkey and given in Table 2. According to the results; there 15 field operations depend on field soil texture, climate conditions. Growing of sunflower was started after harvesting wheat on July 2016 and finished by harvesting on September 2017.

In this study, soil samples from 20 points were taken from 0-30 cm and 30-60 cm depth. Soil samples were analysed for determining soil texture, saturation point (%), pH at saturated soil, Lime (%), total salinity (%), $CaCO_3$, organic matter, useful P (P_2O_5), useful K (K_2O), field capacity (%), and wilting point (%) and salinity (%) Tuzuner (1990). In addition, changing of biomass were determined. Variety of sunflower was Limagrain LG 5542. Samples of biomass were determined for each two weeks during growing season. Number of plants for each sample was 6 plant/m^2 because sunflower planted at 70 cm between rows and 25 cm on rows. Plants were dried in a heating and drying oven 48 hour at 65^{o}C. Biomass was measured for wet and dried plant stems and roots. Results measured as kg/m^2 but presented as t/ha.
Soil samples were taken from 0-30 cm and 30-60 cm from the field. Sampling points and elevation of the field were given in Figure 2.

Table 1. Sunflower field operations

Planting	Date	18/04/2015
	Sowing rate	Between rows: 70 cm, on row: 25 cm
Fertilisation	Date	15/04/2015
	Fertiliser	20-20-0 (N-P-K)
	Fertilisation rate	170 kg/ha
Spraying	Date	29/05/2015
	Herbicide	IMAZAMOX
	Rate	2.0 l/ha
Harvest	Date	04/09/2015

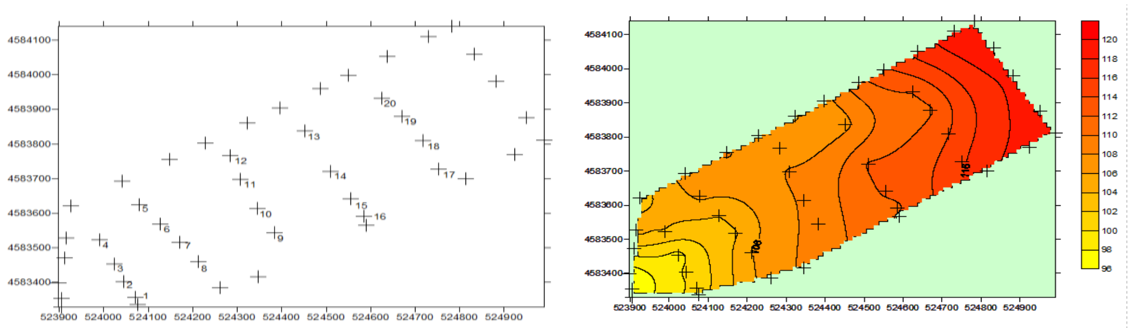

Figure 2. Sampling points and elevation map in the field

Table 2. Sunflower mechanization

Field operations	Month	Width (m)	Speed (km/h	Efficiency (%)	Effective Capacity (ha/h)	Average Fuel Consumption (l/ha)	Man labour requirement (h/ha)
Plough	July	1.40	6	0.80	0.67	30.00	1.190
Disc Harrow	August	3.00	9	0.85	2.30	12.00	0.370
Sprayer	August-September	16.00	14	0.65	14.56	3.50	0.045
Disc Harrow	September	3.00	9	0.85	2.30	12.00	0.370
Rotary tiller	September	3.00	5	0.85	1.28	25.00	0.667
Fertiliser spreader	September	16.00	14	0.70	15.68	3.50	0.045
Harrow	September	4.00	15	0.85	5.10	4.50	0.167
Roller-packer	September	5.00	12	0.85	5.10	4.50	0.167
Sowing machine	October	3.00	7	0.65	1.37	12.00	0.476
Roller-packer	October	5.00	12	0.85	5.10	4.50	0.167
Fertiliser spreader	December	16.00	14	0.70	15.68	3.50	0.045
Sprayer	February	16.00	14	0.65	14.56	3.50	0.045
Fertiliser spreader	March	16.00	14	0.70	15.68	3.50	0.045
Sprayer	March	16.00	14	0.65	14.56	3.50	0.045
Harvesting	May-June	5.20	8	0.70	2.91	20.00	0.240
TOTAL						145.50	4.082

RESULTS AND DISCUSSION

Soil texture, saturation point (%), pH at saturated soil, Lime (%), total salinity (%), $CaCO_3$, organic matter, useful P (P_2O_5), useful K (K_2O). Soil analysis results were given in Table 3. These results were used to create spatial variability maps.

Results of soil analyses for 0-30 cm depth were given in (Table 3). and 30-60 cm in (Table 4). According to the results; soil texture was generally determined as Clay but there also were Sand-Clay-Loam and Clay-Loam soil textures in the research field. Mean values and standard deviations for saturation point 57.35% and 7.44%, pH 7.30 and 0.66, Salt 0.07 and 0.01, lime 7.63 and 0.68, organic material 1.29% and 0.17%, able 3.Soil analyses results for 0-30 cm soil depth P_2O_5 18.22 and 2.52, K_2O 146.05% and 30.82, field capacity 30.34% and 4.07%, and for wilting point 19.18% and 2.72.

According to the results: Soil texture was mostly clay but clay loam and sandy clay loam textures were also determined. Mean values and standard deviations were calculated a 57.35% and 7.44% for

Sample no	Saturation %	pH	Salinity %	Lime % $CaCO_3$	Organic Matter %	Useful P_2O_5 kg/da	Useful K_2O kg/da	Texture % Clay	Texture % Silt	Texture % Sand	Texture class	Field capacity %	Wilting point %
1	56	7.14	0.06	5.6	1.64	17.52	195	41.67	14.58	43.75	Clay	36.06	23.96
2	60	7.31	0.05	6.7	1.28	21.37	142	31.25	14.58	54.17	Sandy clay loam	28.17	18.45
3	50	5.96	0.05	-	1.33	15.77	166	31.25	14.58	54.17	Sandy clay loam	25.35	17.39
4	45	6.22	0.06	-	1.26	15.15	125	33.33	16.67	50.00	Sandy clay loam	26.05	17.90
5	47	6.12	0.05	-	1.15	16.99	182	41.67	20.83	37.50	Clay	33.56	20.74
6	47	6.19	0.05	-	1.24	16.99	197	39.58	22.92	37.50	Clay loam	31.63	21.15
7	46	6.7	0.07	-	1.42	16.38	188	45.83	18.75	35.42	Clay	36.44	26.42
8	48	7.76	0.07	7.6	1.24	16.99	107	41.67	25.00	33.33	Clay	33.56	20.74
9	66	7.67	0.08	8.3	1.22	22.07	188	45.83	27.08	27.08	Clay	37.08	20.68
10	70	7.52	0.08	8.5	1.11	25.58	107	54.17	16.67	29.17	Clay	34.41	22.41
11	62	7.73	0.07	8.0	1.74	20.06	105	52.08	20.83	27.08	Clay	31.95	19.37
12	61	7.65	0.07	7.8	1.18	20.06	113	47.92	20.83	31.25	Clay	28.31	17.42
13	64	7.61	0.09	7.8	1.19	18.83	145	52.08	18.75	29.17	Clay	31.95	19.37
14	64	7.71	0.08	7.7	1.44	18.83	147	54.17	18.75	27.08	Clay	34.41	22.41
15	61	7.63	0.08	7.6	1.34	17.52	150	50.00	18.75	31.25	Clay	25.13	21.38
16	60	7.69	0.07	7.6	1.20	17.52	120	50.00	16.67	33.33	Clay	38.38	24.50
17	60	7.83	0.08	7.8	1.32	16.38	137	47.92	20.83	31.25	Clay	28.31	17.42
18	60	7.84	0.08	7.8	1.09	16.38	120	54.17	18.75	27.08	Clay	34.41	22.41
19	60	7.84	0.08	7.8	1.21	16.99	150	54.17	20.83	25.00	Clay	36.72	25.56
20	60	7.84	0.08	7.8	1.12	16.99	137	52.08	18.75	29.17	Clay	31.95	19.37

saturation point, 7.30 and 0.66 for pH, 0.07 and 0.01 for salt, 7.63 and 0.68 for lime, 1.29% and 0.17% for organic material, 18.22 and 2.52 for P_2O_5, 146.05% and 30.82 for K_2O.

Results of soil analyses were given in (Table 3 in Table4) for 0-30 cm and 30-60 cm depth respectively.

Soil texture, saturation point (%), pH at saturated soil, Lime (%), total salinity (%), $CaCO_3$, organic matter, useful P (P_2O_5), useful K (K_2O) were investigated. Soil analysis results were given in (Table 3). These results were used to create map of analysed soil parameters (Figure 3).

The test area consists of Vertisols, which can be understood from soil analysis results. Vertisols is dark coloured, heavy or very heavy textured and contains low organic matter. They are usually dark brown-black with a thick, "A" horizon earth, commonly "dark reddish brown". Clay quantities often do not change or increase very little depending on depth. In our study, we have not seen any significant change in the amount of clay in samples we have taken from 30-60 cm depth. The $CaCO_3$ contents of the soils were generally 5-10%. Vertisols is the most suitable land for sunflower farming, which is deeply rooted in Thrace. Since the colours of vertisols in Thrace are dark, they quickly heat up and cause the surface horizons to dry quickly. Thus, in the lower horizons of the pile rooted plants growing in the vertisols, it is possible to utilize for a longer period of time than the higher water level which is higher than other soils such as
sandy and loamy textures. The productivity and plant nutrient levels of the vertisols are generally good because of the low content of organic matter, all cultivated plants should be fertilized with nitrogenous fertilizer Dinc (1995).

Table 4.Soil analyses results for 30-60 cm soil depth

Sample	Texture % Clay	% Silt	% Sand	Texture class	Field capacity	Wilting point.
1	43.75	14.58	41.67	Clay	34.41	22.71
2	29.17	14.58	56.25	Sandy clay loam	22.67	12.53
3	31.25	14.58	54.17	Sandy clay loam	27.75	19.47
4	29.17	12.50	58.33	Sandy clay loam	24.26	15.69
5	47.92	18.75	33.33	Clay	36.64	24.81
6	39.58	27.08	33.33	Clay	32.09	22.79
7	43.75	18.75	37.50	Clay	23.93	11.77
8	47.92	20.83	31.25	Clay	21.64	14.70
9	43.75	22.92	33.33	Clay	27.67	14.64
10	52.08	18.75	29.17	Clay	26.25	14.79
11	47.92	20.83	31.25	Clay	27.61	17.13
12	50.00	20.83	29.17	Clay	23.19	11.06
13	54.17	18.75	27.08	Clay	34.41	22.41
14	50.00	20.83	29.17	Clay	23.19	11.06
15	50.00	18.75	31.25	Clay	30.17	15.92
16	47.92	16.67	35.42	Clay	26.63	10.95
17	50.00	22.92	27.08	Clay	24.74	18.21
18	47.92	20.83	31.25	Clay	35.94	23.83
19	54.17	20.83	25.00	Clay	36.14	24.51
20	45.83	16.67	37.50	Clay	36.44	26.42

Nitrogen fertilisation was determined by using organic matter of soil samples. Other fertilisation recommended according to the pH values. Fertiliser with P and K don't recommended because of their contents in the samples were found too much. Fertiliser with Nitrogen was suggested as 90 kg/ha to establish 1.1-1.2% organic matter in research field soil Gucdemir (2006). Pure Nitrogen requirement was found constant but there were variability for soil texture and pH. Consequently, Ammonium Sulphate fertiliser (21%) recommended as 285 kg/ha for field parts where pH were found higher than 7.0 and Urea (46%) was recommended for the areas where pH lower than 7.0 Calcium Ammonium Nitrate (CAN 26 %) with first hoeing was suggested at 11.5 kg/ha application rate for top dressing fertilisation. Fertiliser requirement was determined by using soil analysis data and spatial variability maps. Results were given in (Table 5).

Required amount of pure nitrogen (N) was determined by using organic matter results. Nitrogen requirement was determined as 90 kg/ha. for all field but type of the fertiliser which includes nitrogen (N) was determined by using pH variability. According to the results, amount of available phosphorous (P) and potassium (K) were higher than required for sunflower growing. Fertilisers will be 285 kg/ha Ammonium Sulphate (21%N) and 115 kg/ha Calcium Ammonium Nitrate (26%N) for constant rate fertiliser application. If this fertiliser will be applied as variable rate by taking into account pH variability from (Table 2), type of the fertiliser will be changed. Consequently, amount of fertilisers will be 115 kg/ha Calcium Ammonium Nitrate (26%N) for whole field and 285 kg/ha Ammonium Sulphate (21%N) should be applied for 250 ha. field size and 130 kg/ha Urea (%46 N) suggested for 100 ha. When we evaluate application in the research field; application rate of 20-20-0 (N-P-K) mineral fertiliser was 170 kg/ha. Fertilisation rate was 34 kg/ha for pure nitrogen (N) and 34 kg/ha for pure phosphorous.

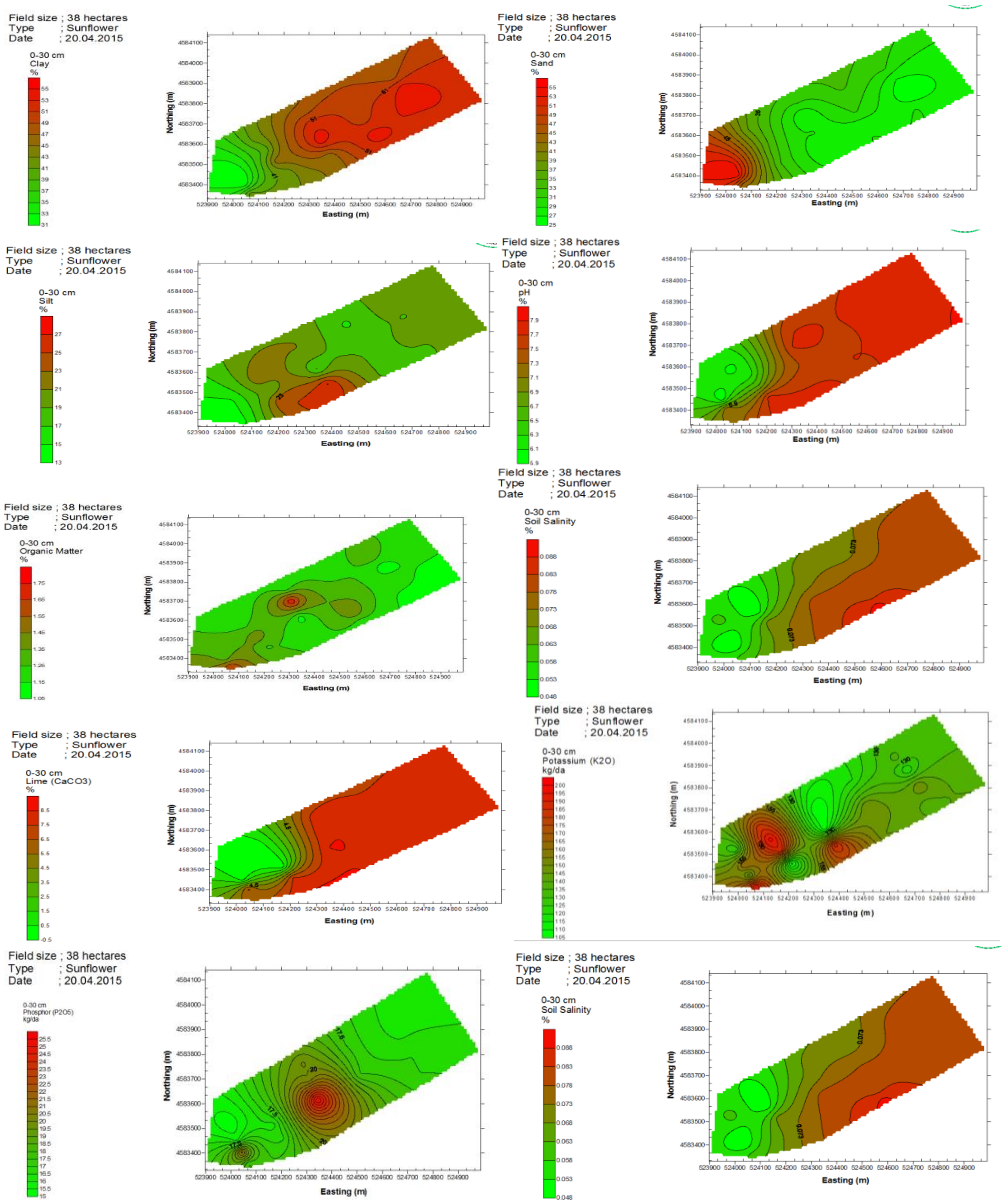

Figure 3. Spatial variability in research field soil parameters

Table 5. Required fertiliser due to soil analysis results

Sample number	Available Nutrients**		Required pure N (kg)		At sowing %21 Ammonium Sulphate (kg/da)	When sowing Urea (% 46 N) (kg/da)	When 1st hoeing % 26 CAN (kg/da)
	P (P_2O_5) kg/da	K (K_2O) kg/da	at sowing	At 1st hoeing ***			
1	17.52	195	6	3	28.50		11.50
2	21.37	142	6	3	28.50		11.50
3	15.77	166	6	3		13.00	11.50
4	15.15	125	6	3		13.00	11.50
5	16.99	182	6	3		13.00	11.50
6	16.99	197	6	3		13.00	11.50
7	16.38	188	6	3		13.00	11.50
8	16.99	107	6	3	28.50		11.50
9	22.07	188	6	3	28.50		11.50
10	25.58	107	6	3	28.50		11.50
11	20.06	105	6	3	28.50		11.50
12	20.06	113	6	3	28.50		11.50
13	18.83	145	6	3	28.50		11.50
14	18.83	147	6	3	28.50		11.50
15	17.52	150	6	3	28.50		11.50
16	17.52	120	6	3	28.50		11.50
17	16.38	137	6	3	28.50		11.50
18	16.38	120	6	3	28.50		11.50
19	16.99	150	6	3	28.50		11.50
20	16.99	137	6	3	28.50		11.50

According to the soil analyses; nitrogen application will be 90 kg/ha and there wasn't requirement for phosphorous application for this research field. They did not applied required nitrogen. Differences between requirement and application was 56 kg/ha. There was no requirement for phosphorous (P) but applied 34 kg/ha.

Biomass measurements were started at 13th May, 2015 and finished at 19th August, 2015 for each two weeks (Figure 4.).

Even vegetative growing reached at maximum value in June, 2015, both wet (*63,95 t/ha.*) and dry (*16,19 t/ha.*) aboveground biomass of plant reached maximum value on 5th August, 2015 when evaluated sunflower plant growing. As the harvesting period was approached, the growth of the plant, which is the generative part of the plant, resulted in higher levels of biomass, such as table, stem and leaf, than expected from the amount of biomass from the stem and leaf before the formation of the table.

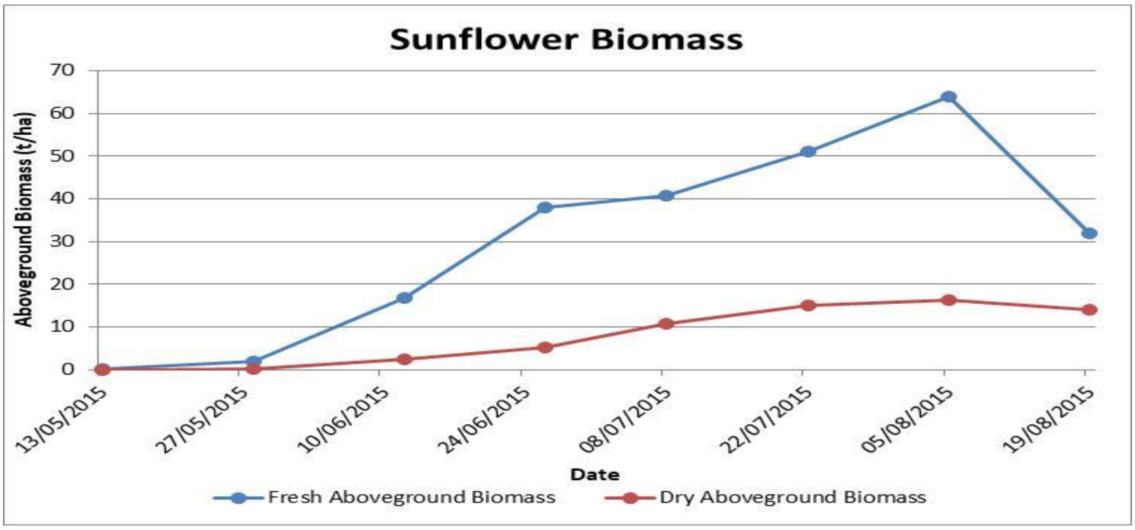

Figure. 4. Above-ground Fresh and Dry Biomass Amounts of Sunflower

CONCLUSION

Sunflower is the second important crop after wheat in Thrace Region. Determination of the spatial variability for soil properties and plant nutrients is first step of the precision farming. Variable rate application of the agricultural inputs such as fertilizer, spraying and irrigation starts with the determination of the spatial variability. In addition, spatial variability should be determined in agricultural production because it affects yield, quality and production cost (Ferrerao et al., 2013). There is always spatial variability for yield, soil specifications and quality of the productions. Farmers generally don't take into account spatial variability in the field even they know when they look their field.

Spatial variability of the soil properties and biomass were determined for sunflower growing in this research, Amount of the fertiliser requirement was affected by spatial variability of soil properties. The results showed that there was differences required and used amount of the nitrogen and phosphorous.

Determining of spatial variability requires analysing of soil, leaves and grains by laboratory analysis or sensors. These analyses also increase cost. Farmer should be careful about cost of the precision agriculture applications such as variable rate applicators and/or yield monitors. Precision agriculture applications cost

ACKNOWLEDGEMENTS

We would like to thank General Directorate of Agricultural Research and Policies (TAGEM) for support of this ICT AGRI ERA-NET project (Smart Good Agricultural Practices- Project No:16174) Additionally, we also thank Ziya Organic Agriculture Management for their cooperation.

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