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EFFECTS OF ANHYDROUS AMMONIA APPLICATION ON YIELD AND YIELD COMPONENT OF SUNFLOWER (*HELIANTHUS ANNUS L.*)

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ABSTRACT

The aim of the research was to determine the effects of Anhydrous ammonia application on yield and yield components of sunflower. Field experiment was conducted in Tekirdag at Trakya Region, Turkey during 2014 and 2015. Three different methods was planned. Anhydrous ammonia application (M1), the traditional condition (M2) and the control (M3). Anhydrous ammonia application was made once before the sowing period. At the M2 is the method used by local farmers. No nitrogen fertilization was at the M3 method. In this research, head diameter, stem diameter, plant height, hull rate, harvest index, 1000 seed weight, grain yield and oil content were investigated. Results showed that Anhydrous ammonia has a positive effect on yield and yield parameters statistically ($P< 0.05$). Significant differences were found between methods each year. The maximum grain yield (312.02 kg da^{-1}) was observed in M1 methods while the minimum seed yield (226.55 kg da^{-1}) was observed in M3 without application of N fertilizer both years.

INTRODUCTION

Sunflower (*Helianthus annus* L.) is one of the most widely cultivated oil crops in the world. In recent years, the planted area has increased because its high oil yield. Sunflower is widely adaptable and more drought tolerant than most other grain crops. In Turkey, sunflower are shown on approximately $500\text{-}600.10^3$ ha. Sunflower was produced on 530.10^3 ha and 1.2 MMT of sunflower seed were harvested in Turkey according to the production data of 2015 (Sirtioglu, 2015). Sunflower cultivation area is mostly 73% located in Trakya Region. In 2014, sunflower production in Tekırdag were 345.785 tone and average yield is calculated as 2.51 ton per hectare. Nitrogen fertilizers are effective on sunflower yield and yield components (Ali *et al.,* 2004; Ozer *et al.,* 2004). Anhydrous ammonia is a chemical compound used as a fertilizer in agriculture. It is a fertilizer containing the highest nitrogen (%82). Anhydrous ammonia (AA), accounts for about 32% of the nitrogen (N) fertilizers used in the U.S. Over the years, AA has proven to be a reliable and cost effective source of N (Terry and Kirby, 2006).

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Anhydrous ammonia will stay in liquid form when stored under its own pressure which is dependent on temperature. While liquid under high pressure, It turns to a gas under atmospheric pressure. At 21º C, AA will create a tank pressure of about 8 kilograms per square centimeter (Hanna, 2001). Physical and chemical properties of Anhydrous ammonia, which create problems for the application and storage of AA. It can be also caused damage on the human body. Special tools and equipment are needed at the storage and application stages due to the chemical properties. Therefore, the use of the Anhydrous ammonia for fertilizer is undeveloped in our country agriculture (Akar *et al.,* 2015). AA must be injected directly into the soil and covered immediately to prevent ammonia gas escaping directly to the atmosphere. When AA is injected into the soil, a portion attaches to available soil water to form ammonium while the balance stays the in the ammonia form. The amount and rate are related to AA rate, application method, cation exchange capacity of the soil, soil texture, and soil moisture. Application rate, application spacing, application depth, soil moisture and soil texture were factors affecting loss of AA (Abo-Abda, 1985). Anhydrous ammonia application equipment commonly used in small grains is typically spaced between 38 and 50 cm. Research by Maxwell *et al*., (1984) suggested that spacing up to 50 cm may be adequate for most situations but 30 cm may be more favorable in certain soils and conditions. Teal et al. (2007) found a slight advantage to 10 cm spacing over 46 cm in no-till soils but these results were somewhat inconsistent. They also noted waviness in plant growth associated with the wider spacing but these visible effects did not negatively affect yield. There is no use of anhydrous ammonia fertilizer in Turkey agriculture. Therefore, there are no studies on this subject in crop production. This study also aimed to ensure that the use of anhydrous ammonia fertilizer in our country. This research is a part of our project. The Anhydrous ammonia application equipment made in the research project was conducted in the study. The aim of the research, effects of anhydrous ammonia applications on sunflower were determined.

MATERIAL AND METHODS

Anhydrous ammonia (AA)

Experiment material is Anhydrous ammonia (AA). Ammonia is a chemical compound used as a fertilizer. It is rich in nitrogen (%82). Its chemical formula is NH_3. Chemical and physical properties (Wyckoff, 2009) of AA are shown in Table 1.

Experimental design

Field research was conducted at Trakya Region during the spring season of 2014-2015 (41°8'N, 27°39'W and 41°18'N, 27°47'W). The experiments were arranged in the field using a randomized complete block design with three replications.

In this research, three different methods were used; Anhydrous ammonia, traditional conditions and control. Nitrogen ratio used application was determined according to the soil analysis. The analysis of soil was carried out before sowing the crop. The project was conducted at two sites, both a sandy site and a heavier silt loam site (Table 2.2). Total N rate, row spacing and variety used in 2014-2015 are listed in Table 2.3. Total nitrogen used at the M1 methods were 12.3 kg da $^{-1}$ in 2014 and 12 kg da $^{-1}$ in 2015 year.

The traditional method is the method used by local farmers. At the M2 methos were used 7.6 kg da $^{-1}$ in 2014 and 12.1 kg da $^{-1}$ total nitrogen in 2015 year. At the M2 methods were made in two times (With the fertilizer N in the urea and Ammonium nitrate form). At M2 methods were recorded N fertilizer applied by farmer both years (Table 2.4). The control methods (M3) was no N included. The average rate of N fertilizer applied to sunflower in Trakya Region was 12-15 kg N da^{-1} in dry conditions. In wet conditions, the average rate of N fertilizer is increased by 10%. Important dates at this research are given in Table 2.5. Anhydrous ammonia application was applied on 10th April, 13th March in sunflower in the period before sowing 2014 and 2015, respectively. In this research, head diameter (cm), stem diameter (cm), plant height at maturity (cm), hull ratio (%), harvest index (%), 1000 seed weight (g), seed yield (kg da^{-1}), oil ratio (%) and protein ratio (%) were taken. Data collected from the experiments were statistically analyzed using the computer statistical program SPSS. Mean comparison among treatments were evaluated using the least significance difference (LSD) test at P = 0.05 for yield and yield components of the sunflower crop.

Table 2.1. Physical and chemical properties of Anhydrous ammonia

Physical Form	Gas (liquid under pressure)
Color	Colorless gas and liquid,
Odor	Strong pungent penetrating odor, ammonia
Boiling Point	-33° C at 1 atm
Specific Gravity	0.6818 (-33.35° C and 1 atm)
Melting point	-78° C
Ph	Approximately 12.0 (neat)
Vapor Density	0.597 (0° C)
Vapor Pressure	7.600 mm Hg (25° C)
Molecular Weight	17.03
Density	0.696 g/L
Critical Temper.	133° C

Table 2.2. Site soil information

Year	Soil Series	pH	OM (%)	N (%)	P (ppm)	K (ppm)
2014	Sandy	6.87	1.37	0.07	21.16	132
2015	Clay-loam	6.38	0.17	0.01	29.0	65

Table 2.3. Total N rate, row spacing and variety used in experiments

Treatment	Variety	Method	Row spacing (cm)	Total N rate (kg da^{-1})
2014	Pioneer64LC108	Anhydrous ammonia (M1)	50	12.3
		Traditional (M2)	50	7.6
		Control (M3)	-	-
2015	Pioneer 64LL62	Anhydrous ammonia (M1)	50	12
		Traditional (M2)	50	12.1
		Control (M3)	-	-

Table 2.4. Total nitrogen rate applied at the traditional methods (M2)

Application period of N	2014	2015
Before sowing stage	20 kg (15-15-15)	15 kg urea (% 46)
Hoeing stage	10 kg urea (% 46)	20 kg nitrate (% 26)
Total N rate	7.6 kg da^{-1}	12.1 kg da^{-1}

Table 2.5. Important dates at the Anhydrous ammonia application

2014	Application	10 April 2014
	Cultivation	12 April 2014
	Harvest	16 September 2014
	Application	13 March 2015
2015	Cultivation	16 March 2015
	Harvest	31 August 2015

Table 3.1. Effects of the methods on yield parameters

Y		HD (cm)	SD (cm)	PH (cm)	HR (%)	HI (%)
	M1	21.15±2.9 b	1.53±2.4 b	139 ±9.5 b	99.6±0.8 b	40.24±2.1 ^{ns}
1	M2	18.75±2.8 a	1.53±2.4 b	137.8±6.7 b	98.3±1.7 a	37.38±4.2 ^{ns}
	M3	17.35±3.0 a	1.30±2.3 a	130.0±9.8 a	97.6±2.1 a	39.00±4.5 ^{ns}
		19.08±3.3	1.46±2.6	135.6±9.5	98.5±1.8	38.87±3.7
	M1	20.40±2.43 b	1.56±3.2 a	138.0±24.0 b	99.9±0.2 b	37.65±5.0 ^{ns}
2	M2	17.55±3.05 a	1.68±3.9 a	124.0±11.1 a	99.5±0.7 a	40.45±4.5 ^{ns}
	M3	16.30±2.69 a	1.99±2.1 b	121.0±10.0 a	99.6±0.8 a	36.02±8.4 ^{ns}
		18.08±3.20	1.74±3.6	127.6±17.7	99.7±0.6	38.04±6.1
	M1	20.77±2.72 c	1.55±2.85 ^{ns}	138.5±18.0 b	99.7±0.6 b	38.9±3.9 ^{ns}
	M2	18.15±2.98 b	1.60±3.35 ^{ns}	130.9±11.4 a	98.9±1.4 a	38.9±4.4 ^{ns}
	M3	16.82±2.90 a	1.65±4.11 ^{ns}	125.5±10.8 a	98.6±1.9 a	37.5±6.6 ^{ns}
		18.58±3.29	1.60±3.47	131.6±14.7	99.1±1.5	38.4±5.0
	S.D	F				
Y	1	3.65**	30.53*	10.91*	27.55*	0.23^{ns}
M	2	19.71*	1.16 ^{ns}	9.86*	8.62*	0.30^{ns}
YxM	2	0.06^{ns}	15.29*	2.439**	4.48**	1.28^{ns}
E	114					

*P<0.05;
**P<0.01;
ns; No Significant
HD, Head diameter (cm); SD, Steam diameter (cm); PH, Plant height (cm); HR, Hull ratio (%); HI, Harvest ındex (%);
M1, Anhydrous ammonia methods; M2, Traditional conditions and M3, Control methods.
Y, Year;
M, Methods;
YxM, Year x Methods; E, Error;

Table 3.2. Effects of the methods on yield and Thousand grain weight (g), Oil content (%)

Y		TGW (g)	GY (kg·da^{-1})	OC (%)	PY
	M1	55.28±8.0 b	334.98 b	39.20±0.6 ^{ns}	468.98 b
1	M2	39.98±3.5 a	242.74 a	37.66±1.4 ^{ns}	339.84 a
	M3	44.05±6.1 a	222.39 a	39.06±1.4 ^{ns}	311.36 a
		46.43±8.8	266.70	38.64±1.3	373.39
	M1	61.83±10.6^{ns}	289.07 b	46.01±1.7 ^{ns}	404.70 b
2	M2	58.33±10.4^{ns}	262.64 a	45.81±2.6 ^{ns}	367.70 a
	M3	52.50±9.3^{ns}	230.71 a	44.33±1.4 ^{ns}	323.0 a
		57.55±10.3	260.81	45.38±2.0	365.13
	M1	58.55±9.6 b	312.02 b	42.61±3.7 ^{ns}	436.84 b
	M2	49.15±12.1 a	252.69 a	41.74±4.7 ^{ns}	353.77 a
	M3	48.27±8.7 a	226.55 a	41.69±3.0 ^{ns}	317.18 a
		51.99±11.0	263.75	42.01±3.8	369.26
	S.D				
Y	1	15.69*	0.085^{ns}	146.73*	0.08
M	2	5.50*	6.22**	1.14^{ns}	6.22**
YxM	2	1.699^{ns}	1.002	2.23^{ns}	1.00
E	114	24			

*P<0.05;
**P<0.01;
ns; No significant
TGW, Thousand grain weight (g); GY, Grain yield (kg·da^{-1}); OC, Oil content (%); PY, Plot yield
M1, Anhydrous ammonia methods; M2, Traditional conditions and M3, Control methods.
Y, Year;
M, Methods;
YxM, Year x Methods; E, Error;

Knife-injected Anhydrous ammonia (AA)

AA was injected 15-20 centimeters beneath the soil surface to ensure maximum absorption by the soil. Injection unit is traditional knife type (space 50 cm.)

In the experiments, the anhydrous ammonia application equipment developed at the TAGEM AR-GE project was used. Knife type and equipment used at experiments are illustrated in Figure 1.

Figure 2.1. An example from experiments

RESULTS AND DISCUSSION

Effects of the methods on yield parameters are presented in Table 3.1. There was statistically significant effects of the methods on yield and yield parameters ($P < 0.05$).

Head diameter

The results in Table3.1 showed significant differences in head diameter at methods ($P<0.05$). In M1 methods had higher head diameter (20.77 cm) followed by M2 methods (18.15 cm), while statistically lower head diameter (16.82 cm) was observed in M3 methods. The higher head diameter were in M1 methods both years. The same nitrogen amounts for M1 and M2 methods were used in 2015. But, the head diameter in M1 methods was measured higher than M2 method. These results demonstrate that has a significant effect of Anhydrous ammonia on the head diameter. Sarfaraz *et al.,* (2014) and also reported by Awais et al. (2013) similar head diameters (between 15.89-18.11 cm) with this study. Foroud and Bohrani (2000) indicated significantly increasing seed yields and head diameters with increasing nitrogen doses.

Steam diameter

M1 methods and M2 methods showed similar results for steam diameter both years. But, in the M3 method, the stem diameter showed variable results between years. The highest steam diameter was found in the M3 methods. M1 methods and M2 methods were found statistically a similar group ($p<0.05$). These results demonstrate that has no a significant effect of Anhydrous ammonia on the steam diameter.

Plant Height

Effects of applied methods on plant height ($p<0.05$) and year x methods interactions were found to be significant ($p<0.01$). In M1 methods had higher plant height 139 cm, 138 cm in 2014 and 2015, respectively. These results demonstrate that has a significant effect of Anhydrous ammonia on the plant height. In M2 methods was 130.9 cm while in M3 methods lower plant height 125.5 cm was observed. Mean plant height observed in the year 2014 (135.6 cm) was higher than the plant height observed in the year 2015 (127.6 cm). Such a difference may be resulted from variety properties, climate and environmental conditions. These results are in accordance with (Ergen and Saglam, 2005; Gül and Kara, 2015).

Hull Rate

Hull rate were found to be significant over the years ($P<0.05$). In M1 methods had higher hull rate both year (% 99.7) followed by M2 methods (% 98.9), while statistically lower hull rate (% 98.6) was observed in M3 methods. M2 methods and M3 methods were found statistically a similar group ($p<0.05$). These results demonstrate that has a significant effect of Anhydrous ammonia on the hull rate. Hull rate at the different methods shown in Figure 1. The methods used Anhydrous ammonia, it was observed that filled the interior of the circle in the center of the sunflower.

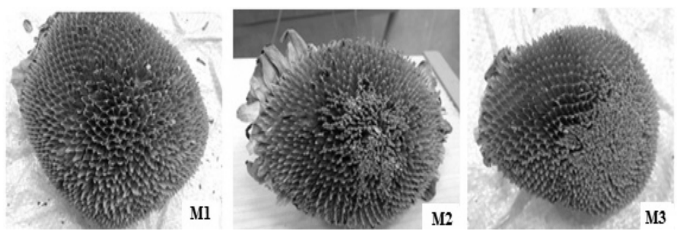

Figure 3.1. Hull rate at the different methods

Harvest Index

Effects of methods applied in experiment on harvest index (HI) were no significant. Gül and Kara (2015) reported similar results with this study. They indicated that effects of nitrogen doses in harvest index were not found to be significant. Harvest index of the years 2014 and 2015 were respectively observed as 38.87.% and 38.04 %. The lowest harvest index values were observed in M3 methods (36.02 %).

Thousand Grain Weight

Maximum thousand grain weight was observed in M1 methods both year (55.28 and 61.83 g) while minimum thousand grain weight was observed (39.98 g) in M2. The average minimum thousand grain weight (35.5 g) was obtained by the M3 methods without application of nitrogen fertilizer (Table 3.2). A significant correlation was estimated between thousand grain weight and grain yield (-,516**; P<0.01). Ozturk *et al.,* (2008) indicated significantly increasing seed yields and thousand grain weight with increasing nitrogen doses.

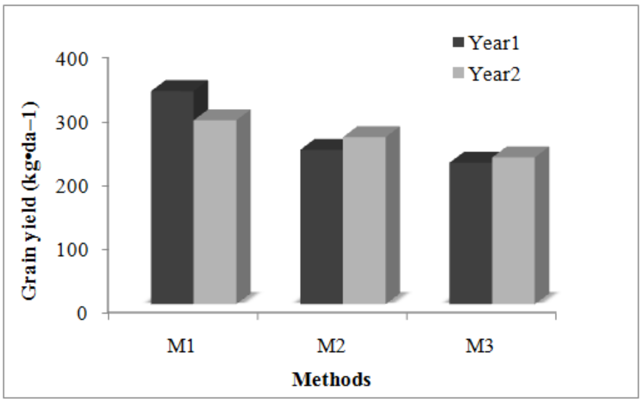

Figure 3.2. Effects of the methods on grain yield according to years

Grain Yield

There was significant effects of the applied methods in experiments on grain yield (P<0.05). The minimum grain yield (226.55 kg·da^{-1}) was observed in M3 methods where there was no application of nitrogen fertilizer. The highest Grain yields was in M1 methods. Grain yields were 312.02 kg·da^{-1}, 252.69 kg·da^{-1} and 226.55 kg·da^{-1} in M1, M2 and M3 methods, respectively (Fig.3.2). M2 and M3 methods were statistically similar groups. These results demonstrate that has a significant effect of Anhydrous ammonia on the grain yield. A significant correlation was estimated between the methods applied in the trial and grain yield (-.684**; P<0.01). Tenebe *et al.,* (1996); Gholinezhad *et al.,* (2009); Ali *et al.,* (2012) and Nasım *et al.,* (2012) reported increasing seed yields with increasing nitrogen doses.

Oil Content

There was no istatically significant effects of the applied methods in experiments on oil content (P>0.05). The highest oil content regardless of the variety special both years was measured at the M1 methods 39.2% in 2014 and 46.1% in 2015. This result shows that has no significant effect of Anhydrous ammonia on the oil content. Al-Thabet, (2006); Hussain *et al.,* (2011) and Gül and Kara, (2015) reported that oil content decreased with increasing nitrogen doses but, grain yield increased.

Conclusions

Results showed that Anhydrous ammonia has a positive effect on yield and yield parameters of sunflower. The anhydrous ammonia method compared to the M2 method, the first year 38% and the second year 11% more grain yield was obtained. Anhydrous ammonia application equipment which is developed within the project and involved this into agricultural production is important for possible significant development of Turkish agricultural industry.

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