Tr. J. of Agriculture and Forestry
23 (1999) 393-399

Effect of Phosphorus Fertilizers and Application Methods on the Yield of Wheat Grown Under Dryland Conditions*

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Received: 28.03.1998

Abstract: This study was conducted to investigate the efficiency of diammonium phosphate (DAP) and triple superphosphate (TSP) as phosphorus (P) sources and the effect of fertilizer application methods on the grain yield, yield components and other characteristics of winter wheat. The research was conducted in the ecological conditions of Tokat–Kazova during the 1990–1991 and 1991–1992 growing seasons. Bezostaja–I and Kırkpınar–79 cultivars were used as the plant materials. DAP and TSP fertilizers were applied according to four different methods, i. e., broadcasting, with seed, application 5 cm to the right and left of the seed and 5 cm below the seed.

The effects of DAP and TSP on the characteristics examined were not significant. Effects of the application methods on emergence period, the number of plants/m^2 and grain yield were found to be significant in the first year, whereas all characteristics were affected significantly in the second year. The maximum grain yield was obtained from application 5 cm below the seed in both years.

Fosforlu Gübre ve Uygulama Yöntemlerinin Kurak Şartlarda Buğday Verimine Etkisi

Özet: Bu çalışma, fosfor kaynağı olarak kullanılan DAP ve TSP ile bunların uygulanış şeklinin kışlık buğdayda tane verimi ve verim komponentleri ile bazı özelliklere etkisini araştırmak amacıyla yapılmıştır. Araştırma 1990–91 ve 1991–92 vejetasyon döneminde Tokat–Kazova koşullarında yürütülmüştür. Çalışmada bitki materyali olarak Bezostaja–I ve Kırkpınar–79 çeşitleri kullanılmıştır. DAP ve TSP; serpme, tohumla birlikte, tohumun 5 cm sağına ve soluna ve 5 cm altına olmak üzere dört farklı şekilde uygulanmıştır.

Araştırmada incelenen özelliklere DAP ve TSP'nin etkisi önemsiz bulunmuştur. Gübre uygulama yöntemlerinin ilk yıl çıkış süresi, m^2'de bitki sayısı ve tane verimine, ikinci yıl ise bütün özelliklere etkisi önemli bulunmuştur. Her iki yılda da en yüksek tane verimi gübrenin tohumun 5 cm altına uygulandığı muameleden elde edilmiştir.

Introduction

Efficient use of phosphorus fertilizers is important from both an economic viewpoint and the conservation of the world's phosphate resources. There are several methods of P placement. Broadcasting is the most common method of aplication on wheat fields. However, in soils with high phosphate fixation and low levels of available P, the applications of P in bands generally increases productivity relative to broadcasting (1). Peterson et al. (2) found that with winter wheat *(Triticum aestivum L.)* in low P soils, the effectiveness of row placement may be three to four times that of broadcasting. It has been reported that banding phospate with wheat seed gives early availability of P, and in many cases total dry matter and grain production increased, even in soils with medium–to–high levels of available P (3). Banding below the seed at the time of planting has the added advantage of placing the fertilizer in immediate contact with the emerging radicle and seminal roots during seedling establishment (4). McConnel et al. (5) cited that with medium–to–high soil P these methods were equally effective. The advantage of placement varies with soil type, application rate (1, 6), pH and soil texture (7) and the amount of precipitation in the growing season (5).

However, high doses of fertilizer given with seed have a negative effect on germination (8–11). This negative effect is higher in light–textured soils and in conditions where there is limited moisture. Kashwa and Sing (12) have reported that banding under the seed or broadcast application of P does not affect the grain yield of wheat. Banding may have a negative effect on the yield when high doses of fertilizer are applied and when water stress occurs (13, 14).

* The article is part of the Ph. D. thesis.

The effect of a fertilizer depends on the biological, chemical and physical factors of the soil. The relative efficiency of P sources depends largely on their water–soluble phosphorus content as a high degree of water–soluble phosphorus encouranges early–season growth in small–grain cereals (15). DAP and TSP are the most prevalent sources of P fertilizer used in Turkey. Comparisons of sources of P have not indicated consistent differences in performance with wheat (6, 16).

The aim of this study was to determine the effect of DAP and TSP and different application methods on grain yield, yield components and some other characteristics of winter wheat in Tokat–Kazova.

Materials and Methods

The experiment was conducted in Kazova Plain in Tokat during the 1990–91 and 1991–92 growing seasons. The average temperatures of the growing periods in thes years were 0.7 and 2.2 °C lower than the long–term average, respectively. The greatest difference was in the total precipitation during the growing period between the experiment years and the long–term average. The amount of precipitation in the first–year growing period (460.1 mm) was much greater than in the second year (338.6 mm) and greater than the long–term average (384.1 mm). The results of some basic physical and chemical analyses of the surface soil are listed in Table 1.

Bezostaja–I and Kırkpınar–79 cultivars were the plant materials; and DAP (46% P_2O_5 and 18% N) and TSP (42% P_2O_5) fertilizers were the P sources used in the experiment. Each fertilizer was applied according to four different methods; a) broadcasting, b) with the seed, c) 5 cm to the right and left of the seed, and d) 5 cm below the seed.

All the plots were fertilized with 10 kg/da N and 10 kg/da P_2O_5, according to soil–test results (17). Ammonium sulfate (21% N) was used as the nitrogen fertilizer. When DAP was applied, the amount of N in the DAP was subtracted from the total amount needed; thus the amount of nitrogen was kept constant in each part of the experiment (18).

Experimental design was split–split plot with four replications. Varieties were investigated in the main plots, fertilizers in the sub–plots and application methods in te sub–sub plots. Sub–sub plots were 1.4 x 5.0 = 7 m^2 in size and consisted of eight rows. Seeds were sown 17.5 cm apart in rows with a density of 500 plants per square meter. Sowing was performed by hand.

The total quantity of P fertilizer was applied during sowing, together with half of the N. The rest of the N was applied in the joint growth stage. Since the soils were rich in potassium (K), K was not applied. Herbicide was applied in order to control wide–leaf weeds before the joint growth stage.

Measurements were taken and observations were made according to the methods described by Genç (19) and Tuğay (20). An analysis of variance was used to determine the significance of the treatments and the differences between the treatment methods were determined using the Least Significant Difference (21).

Results and Discussion

Emergence Period

The sources of P did not influence the emergence period significantly (Table 2). No significant differences were noted in the period of emergence in terms of fertilizer application except for seed–fertilizer contact (Table 3). In the case of application in contact with the

Table 1. Physical and chemical properties of the 0–20 cm soil layer.

	Experimental Year	
	1990–1991	1991–1992
Particle Size Analysis		
% Clay	12.7	29.3
% Silt	37.0	44.8
% Sand	50.3	26.4
% Lime	22.1	15.0
Texture	Loamy	Clay loam
pH	7.8	8.2
% C (Organic)	1.97	1.61
Available P_2O_5 at sowing (kg/da)	0.69	0.92

Table 2. Analysis of variance showing the effect of different P sources and methods of P application on winter–wheat emergence, number of plants/m^2, number of spikes/m^2, from heading to maturity.

Source of variation	Emergence		No. of plants/m^2		No. of spikes/m^2		Heading–maturity	
	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92
Main plots								
Blocks	NS	NS	NS	NS	NS	NS	NS	NS
Varieties (V)	NS	NS	NS	NS	NS	NS	**	NS
$Error_1$								
Subplots								
P Sources (P)	NS	NS	NS	NS	NS	NS	*	NS
V x P	NS	NS	NS	NS	NS	NS	NS	NS
$Error_2$								
Sub–subplots								
Methods (M)	**	**	**	**	NS	**	NS	**
V x M	NS	NS	NS	NS	NS	NS	NS	NS
P x M	NS	NS	NS	NS	NS	*	NS	NS
V x P x M	NS	NS	NS	*	NS	NS	*	NS
$Error_3$								
CV%	2.48	5.10	6.47	5.01	19.86	5.74	2.39	2.59

*, ** indicates significance at the 0.05 and 0.01 respectively, NS indicates not significant.

Table 3. Effect of different methods of fertilizer application on emergence, number of plants/m^2, number of spikes/m^2, from heading to maturity.

Treatments	Emergence		No. of plants/m^2		No. of spikes/m^2		Heading–maturity	
	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92
App. methods								
Broadcast	22.3 b	20.8 b	429.5 a	468.8 a	419.4	505.5 b	50.2	49.3 b
With seed	25.5 a	29.1 a	326.9 b	330.7 b	436.6	493.2 b	49.6	49.0 b
R. & L. of seed	22.2 b	21.2 b	426.5 a	470.3 a	442.4	536.8 a	49.6	49.3 b
Under seed	22.4 b	20.2 b	441.7 a	477.0 a	497.3	560.3 a	49.2	51.1 a
LSD	0.652**	1.118**	29.90**	21.04**	NS	28.9**	NS	1.235**
P sources								
DAP	23.1	23.0	398.0	436.8	457.7	509.3	50.1	49.5
TSP	23.1	22.6	414.4	436.6	440.1	538.6	49.2	49.8
LSD	NS	NS	NS	NS	NS	NS	0.69*	NS
Varieties								
Bezostaja–I	22.7	23.0	413.2	435.2	483.8	517.9	47.7	48.9
Kırkpınar–79	23.5	22.6	399.2	438.2	414.0	530.0	51.6	50.4
LSD	NS	NS	NS	NS	NS	NS	2.90**	NS

*, ** indicates significance at the 0.05 and 0.01 respectively, NS indicates not significant.

seed, emergence was delayed by about 3 and 8 days in the first and second years, respectively (Table 3). When fertilizer is in contact with the seed, a delay in germination occurs, resulting from the hygroscopic nature of the fertilizers, prevention of water intake due to the increased water density of the soil and from the osmotic pressure of dissolving fertilizer (8, 9, 10).

Number of Plants Per Square meter

The effect of P sources on the number of plants per square meter was not significant, but effects of the application methods were significant (Table 2). Table 3 shows that the placement of the P fertilizers with the seed decreased total germination, whereas other applications had little or no effect on germination. Other researchers have also noticed that application with the seed can damage seedlings and even cause total failure of the stand (8, 9, 10). The severity of the damage depends to a large extent on the soil moisture content at the time of seeding, the rate of fertilizer application, and the components of the fertilizer used (22). Consequently, the application rate of fertilizer applied with the seed should be kept low.

Number of Spikes Per Square Meter

There was no difference in the types of phosphorus fertilizers in terms of the number of spikes per square meter in either year (Table 2). The effect of different application methods on the number of spikes/m^2 was not significant in the first year but was significant in the second year. The highest values were obtained with fertilizer which was applied below the seed (Table 3). Band–applied phosphorus fertilizers give larger amounts of phosphorus to the wheat plants during the early development stages (7) and, of course, increase the number of spikes per unit area (23).

Heading–Maturity Period

There was no difference betwen DAP and TSP in the second year, but there was a significant effect in the first year. The effects of different application methods, on the other hand, were found to be significant in 1991–1992 but were not significant in 1990–1991 (Table 2). In the second year, with the exception of the fertilizer applied 5 cm below the seed, the application methods produced similar results from the heading to maturity periods (Table 3).

Number of Seeds per Ear

The number of seeds per ear changed significantly according to variety and P source in the second year (Table 4). The effects of different varieties and P sources on this characteristic were not the same in both years.

The type of application method had no effect on the number of seeds pear ear in the first year but had a significant effect (P=0.01) in the second year (Table 4). The maximum number of seeds/ear was recorded with the fertilizers placed 5 cm below the seed. The number of seeds per ear was determined by conditions ranging from inflorescence initiation to anthesis (24). Factors known to influence the number of seeds per ear are day length, light intensity, N levels, water stress and temperature (24). However, Black (25) found that P had no effect on this yield component.

Single Spike Yield

Varietal effects on the single–spike yield were significant, while DAP and TSP ferilizers were found to be similar in this respect in both years (Table 4). The efficiency of P fertilizers is primarily related to water solubility (15). Since DAP and TSP fertilizers are almost the same in terms of water solubility, a similar response from these two fertilizers was not unexpected.

A significant difference in the single–spike yield due to different P application methods was observed in the second year (Table 4). Contrary to the second year, the single–spike yields with different application methods were quite similar in the first year (Table 5). These similar responses might be explained by the higher precipitation and by the light soil texture.

1000 Grain Weight

Varietal effects on the 1000–grain weight were significant only in the first year. The 1000–grain weight of Bezostaja–I was greater than that of Kırkpınar–79 (Table 5). The source of phosphorus had no effect on the 1000–grain weight in either year, but it was greater when DAP had been applied (Table 4 and 5).

The 1000–grain weight was not affected by the treatments in the first year but affected at a 5% level of probability in the second year (Table 4). The seed weight is determined by conditions after anthesis (5), such as temperature and water availability. Applied P does not usually affect seed weight (25). Changes in seed weight due to different application methods were not the same in both years.

Grain Yield

Differences in grain yield between the two wheat varieties differed, depending upon the year (Table 4). In the first year, Bozestaja–I produced a higher yield than Kırkpınar 79, but in the second year Kırkpınar–79 yielded more than Bezostaja–I (Table 5).

The grain yield in the first season (1990/91) was lower than that in the second season. There are two reasons for this. First, heavy precipitation and cool weather had a negative effect on fertilization, so the number of seeds per spike was low. Second, the wheat

Table 4. Analysis of variance showing the effect of different P sources and methods of P application on winter–wheat grain yield and yield components.

Source of	No. of seeds/ear		Spike yield		1000 grain weight		Grain yield	
variation	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92
Main plots								
Blocks	NS	*	NS	NS	NS	NS	NS	NS
Varieties (V)	NS	**	*	**	**	NS	*	NS
$Error_1$								
Subplots								
P Sources (P)	NS	*	NS	NS	NS	NS	NS	NS
V x P	NS	**	NS	NS	NS	NS	NS	NS
$Error_2$								
Sub–subplots								
Methods (M)	NS	**	NS	**	NS	*	**	**
V x M	NS	*	NS	NS	NS	**	*	NS
P x M	NS	NS	NS	NS	NS	NS	NS	NS
V x P x M	NS	NS	NS	NS	NS	NS	NS	NS
$Error_3$								
CV%	15.81	2.41	15.43	1.82	4.74	2.06	11.33	6.99

*, ** indicates significance at 0.05 and 0.01 respectively, NS indicates not significant.

Table 5. Effect of different methods of application on grain yield and yield components.

Treatments	No. of seeds/ear		Spike yield (g)		1000 grain wt. (g)		Grain yield (kg/ha)	
	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92	1990–91	1991–92
App. methods								
Broadcast	27.9	34.9 b	1.00	1.35 b	36.1	40.5 b	1603 b	3220 c
With seed	27.8	33.8 c	0.91	1.35 b	35.4	40.8 ab	1507 b	3448 c
R. & L. of seed	29.2	35.6 ab	1.05	1.37 a	36.0	41.2 a	1710 b	3784 b
Under seed	28.5	36.2 a	1.03	1.38 a	35.7	41.4 a	2138 a	4059 a
LSD	NS	0.814**	NS	0.020**	NS	0.605*	225.1**	243.8**
P sources								
DAP	27.6	35.7	1.00	1.38	36.0	41.0	1900	3680
TSP	29.1	34.6	1.00	1.36	35.6	40.9	1585	3582
LSD	NS	0.96*	NS	NS	NS	NS	NS	NS
Varieties								
Bezostaja–I	30.5	31.2	1.21	1.28	38.4	41.9	1900	3521
Kırkpınar–79	26.2	39.1	0.79	1.45	33.2	40.0	1580	3730
LSD	NS	5.64**	0.32*	0.10**	3.91**	NS	301.3*	NS

*, ** indicates significance at the 0.05 and 0.01 respectively, NS indicates not significant.

plants were subjected to attack by leaf rust in the first year and kernels became shriveled.

The effects of DAP and TSP on grain yield were not significant in either year (Table 4). However, DAP produced greater grain yield than TSP in both years (Table 5). Our findings are confirmed by Keshwa and Singh (12) and Venugopalan and Prasad (15), who concluded that different P sources did not affect grain yield in cereals. Nevertheless, there have been other reports of significant effects of fertilizer type on grain yield (14). The effects of different application methods were more obsvious in the second year. The effects of P placement methods depend on the chemical and physical factors of the soil and annual precipitation. The soil texture of the study area was heavier, the pH was higher (Table 1) and the total annual precipitation was lower in the second year.

The highest grain yield was obtained with the application of fertilizer 5 cm below the seed (Table 5). Early P uptake increases the yield potential of the crops by stimulating the growth and development of the plants (26). Banding below the seed at the time of planting has the additional advantage of placing the fertilizer in immediate contact with the emerging radicle and seminal roots during seedling establishment (4). Deeper placement increases the probability of root cantact, since roots tend to grow at a downward angle (4). Banding phosphorus with ammonium nitrogen can also increase the availability of phosphorus to wheat (4, 28). Shallow–applied P, on the other hand, may be more beneficial when frequent light showers wet the soil surface. These factors are probably responsible for why a given placement method does not always produce similar results in different years and in different soils (5).

Many researchers have reported that application of P in bands is superior to broadcasting in heavier soils and in soils where the available P level is low (2, 11).

Conclusions

The following conclusions are drawn:

1. The effects of DAP and TSP on wheat growth were not different.

2. Fertilizers placed in contact with seed at the time of planting prevent or delay germination and drastically reduce emergence.

3. Our findings and the results of other field experiments indicate that fertilizer placed in a band below the seed effectively prevents damage to young seedlings and may increase yield.

4. The effect of P placement depends on the chemical and physical factors of the soil and on the amount of precipitation.

5. Deep–banding methods are recommended for small grains grown on soils in which the texture is heavier, pH is higher and the total precipitation in the growing season is lower.

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