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EFFECT OF N LEVEL AND SPLITTING DIFFERENT LEVELS OF P ON YIELD OF TWO WHEAT CULTIVARS AND P USE EFFICIENCY ATTRIBUTES USING SPRINKLER IRRIGATION SYSTEM IN SANDY SOIL

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ABSTRACT: ***This investigation was conducted at the Agricultural Research Station of the Faculty of Agric., Zagazig University at Khattara for two growing seasons (2004/2005 and 2005/2006). The study aimed to investigate the response of two wheat cultivars (Sakha 93 and Gemmiza 9) to two N levels (50 and 100 kg N/fad), four P levels (check, 20, 40 and 60 kg P_2O_5/fad) and three P splitting treatments (S_1, at sowing, S_2, ½ at sowing + ½ one month latter and S_3, ½ at sowing + ½ two months latter) on yield and its attributes and P uptake as well as P efficiency attributes under sandy soil conditions using sprinkler irrigation system.***

Gemmiza 9 out yielded Sakha 93 in grain yield (combined data) due to superiority in plant height (2^{nd} season), number of spikes/m^2 (1^{st} season), number of grains/spike (combined), thousand grain weight (combined), harvest index (combined) and total P uptake (combined). No significant cultivar differences could be detected in grain weight/spike, straw yield/fad, and all P use efficiency attributes though Gemmiza 9 had, in most cases higher averages than Sakha 93.

Doubling the level of N to 100 kg N/fad was accompanied by a significant increase in each of plant height, number of spikes/m^2, number of grains/spike, thousand grain weight, grain weight/spike, grain and straw yields/fad and harvest index. The total P uptake (TPU), P translocation efficiency (PTE), P apparent recovery efficiency (PARE) and P agronomic efficiency (PAE) were, also, increased but the P physiological efficiency (PPE) and P utilization efficiency (PUE) were decreased.

The increase of P level up to 60 kg P_2O_5/fad was followed by a significant increase in grain yield/fad and almost all their attributes, but each P increment caused a significant decrease in each of PARE, PPE, PAE, PUE and P agrophysiological efficiency (PAPE).

Data of combined analysis revealed that addition of P as ½ at sowing and ½ one month later produced the highest averages for plant height, number of spikes/m^2, number of grains/spike, grain yield/fad, harvest index, TPU, PTE, PARE, PUE and PAE, but delaying the addition of the second split to two months after sowing produced higher averages for thousand grain weight, grain weight/spike, PPE and PAPE.

Results of the interactions between N and P levels in the two wheat cultivars revealed that optimum grain yield/fad could be maximized to 11.33 and 12.62 ardab/fad in Sakha 93 and Gemmiza 9 due to the addition of a predicted optimum P level of 40.6 and 40.5 kg P_2O_5/fad. These additions could secure a profit of 443.57 LE in Sakha 93 and 489.56 LE in Gemmiza 9. The total profit due to these additions amounted to 2038.4 and 2133.0 LE in the two wheat cultivars, respectively. According to these results, doubling the level of N played a great role in optimizing the level of added phosphorus due to their compensating effects. Also, the partly addition of P as ½ at sowing and ½ one month later increased its uptake and utilization.

Key Words: ***Nitrogen, phosphorus, Yield, Sprinkler irrigation, Sandy soil.***

INTRODUCTION

Wheat is considered the first leading cereal crop all over the world. Sustaining wheat production through maximizing unit land area productivity and increasing the cultivated area is a national target in order to minimize the gab between production and consumption. Sandy soils are considered the main area for agriculture extension. However, production of wheat in these soils is facing many problems, among them the poor soil fertility and thus low N and P contents.

Several workers reported significant varietal differences in yield attributes and yield potentiality among different Egyptian wheat cultivars (Mowafy, 2002; Allam, 2003; Ali, *et al.,* 2004; Allam, 2005; Gaballah, 2005-a; Mehasen and Mohamed, 2005; Table *et al.,* 2005; Abd el-Hameed, 2006; El-Sawi *et al.,* 2006 and Gafaar, 2007).

Regarding the response of wheat to N fertilization under sandy soil conditions, several authors reported significant increase in yield of wheat due to the increase of N level up to 40 and 75.5 kg N/fad (Shaaban, 2006 and Weber *et al.,* 2008). Also, others got yield response when they added 100 kgN/fad (AbdulGalil *et al.,* 1997 and Abd El-Maaboud *et al.,* 2006). However, Tawfelies and Tammam (2005) got similar response when they added 105 kg N/fad. Moreover, Mowafy (2002), Abdul Galil *et al.* (2003), Haikel and El-Melegy (2005) and Mekail *et al.* (2006) found that this response reaching 120 kg N/fad. Furthermore, Allam (2003) and Selim (2004) got higher response when they added 125 kg N/fad. Soliman (2000) found similar higher response, but, to N addition of 180 kg N/fad. In all these responses, the significant increase of yield was attributed to the significant increase of yield attributes. Ashmawy and Abo-Warda (2002) noticed that application of N fertilizer up to 120 kg N/fad caused a significant increase in number of spikes/m^2, number of grains/spike, 1000 grain weight and grain yield/fad. Ali *et al.* (2004) reported that wheat yield and most of its attributes showed a positive response to N application up to 120 kg N/fad. Gaballah (2005-b) observed that application of N fertilizer up to 100 kg N/fad had a gradual effect on grain and straw yields and their attributes.

The importance of tillering as a determinant of the yield of wheat has been recognized (Davidson and Mchevalier, 1990 and Rodriguez *et al.,* 1999). Phosphorus is the most major nutrients because P deficiency limits crop growth, tillering capacity and yield (Sato *et al.,* 1996 and Rodriguez *et al.,* 1999). Some authors reported significant increase in yield of wheat due to the increase of P level ranging from 13 to 25 kg P_2O_5 /fad (Abdul Galil *et al.,* 2003; Sarhan, 2004 and El-Mancy and Kotb, 2006). Other authors reported that wheat responded to more addition of P reaching 31.0 kg P_2O_5/fad (Abdul Galil *et al.,* 1997; Saleem, 2000; Abbas *et al.,* 2001; Abd-Alla, 2002; Abdel-Hameed, 2005; Abd El-Maaboud *et al.,* 2006 and Kotb, 2007) and 45kg P_2O_5/fad (Hegazi and Hassan, 1998 and El-Bana, 2000). Moreover, Aly (1998) and Attia and Aly (1998) reported that wheat yield and most of its attributes showed a positive response to P application up to 46.0 kg P_2O_5/fad for both straw and grain yields/fad.

Yield and its attributes of wheat are affected not only by the rate of P fertilization but also by the timing of P application. The time of P fertilizer application before or after sowing is more effective regarding its fixation. So, the determination of the optimum time of application date will be reducing P fixation (Satorre and Slafer, 1999). Uptake of P is more rapid from jointing to anthesis growth stages, where seventy-five percent of P uptake was translocated to the grain at maturity (Fageria *et al.,* 1997). El-Marsafawy (2000) observed that 15.5 P_2O_5/fad fertilizer application after planting, promote penetration and hence more P absorption before fixation and hence yield attributes. In other study El-Marsafawy *et al.* (2001) observed that all yield and its attributes of sesame were significantly increase when the P fertilizer application was applied at the second irrigation.

Therefore, the present study aimed to find out the response of two wheat cultivars to N and P fertilization levels and splitting of P application on grain yield and its attributes and P uptake and efficiency attributes under sprinkler irrigation in a sandy soil.

MATERIALS AND METHODS

This investigation was conducted at the Agricultural Research Station of the Faculty of Agric., Zagazig University at Khattara for two growing seasons (2004/2005 and 2005/2006). The study aimed to investigate the response of two wheat cultivars to N and splitting of different P levels on grain yield and P uptake and efficiency attributes. A separate experiment was devoted for each cultivar. The soil of the experimental site is sandy in texture where it has a particle size distribution of 89.1, 4.9 and 6.0% for sand, silt and clay, respectively. The soil had an average pH value of 7.7 and organic matter content of 0.28%. The available N, P and K contents were 18.3, 3.4 and 57.8 ppm, respectively (average over the two seasons for the upper 30 cm of soil surface).

A. Factors under study:

A.1. Wheat cultivars : a. Sakha 93 b. Gemmiza 9

A.2. Nitrogen levels : a. 50 kg N/fad b. 100 kg N/fad

These two levels were given in five equal splits from 10 days after sowing and in 14 days intervals. It is worth to mention that a basal dose of 20 kg N/fad was added as an activating dose before sowing. Nitrogen was given in the form of ammonium sulphate (20.5% N).

A.3. Phosphorus levels : a. check b. 20 kg P_2O_5/fad c. 40 kg P_2O_5/fad d. 60 kg P_2O_5/fad

A.4. Phosphorus splitting :

a. S_1 : all amount at sowing b. S_2 : ½ at sowing + ½ at one month later

c. S_3 : ½ at sowing + ½ at two months later

Phosphorus was applied in the form of ordinary superphosphate (15.5 P_2O_5). Potassium sulphate (48 – 52 K_2O) at a level of 50 kg K_2O/fad was added at seedbed preparation. Irrigation was practiced at 4 days intervals using sprinkler irrigation. Wheat followed follow preceded, also by wheat.

A split split plot design with three replicates was used where the main plots were occupied by the N levels whereas P levels and P splitting were allotted in the 1st and 2nd sub-plots, respectively. A separate experiment was devoted for each cultivar. The area of plot was 13.5 m^2 (3 m. in width and 4.5 m. in length) including 20 rows, 15 cm a part. Wheat was sown in the last week of November in rows in the two seasons at a fixed rate of seeding of 400 seeds/m^2 for all the two cultivars under study taking in consideration their test weight. Harvest date was on the first week of May for Sakha 93 and in the second week of May for Gemmiza 9 in the two seasons. The other cultural practices for growing wheat under these conditions were applied.

Grain and straw yields/fad and harvest index were determined from the ten central rows (6.75 m^2). The following straw and grain yields attributes were recorded from an area of 0.5 m^2 which was labled after seedling emergence : plant height, number of spikes/m^2, number of grains/spike, thousand grain weight and grain weight /spike. Grain and straw samples were taken from plants of the forementioned 0.5 m^2 where their P contents were determined using the colorimetrical method according to Jackson (1967). The following measurements were determined :

1. **Grain P uptake (GPU), grain P content × grain yield (kg P/fad).**
2. **Straw P uptake (SPU), straw P content × straw yield (kg P/fad).**
3. **Total P uptake (TPU), 1 + 2 (kg P/fad).**
4. **Phosphorus translocation efficiency (%) (PTE) : (GPU/TPU) × 100.**
5. **Phosphorus apparent recovery efficiency (PARE): (TPU_f –TPU_o/P_a)× 100.**
6. **Phosphorus physiological efficiency (PPE) : (TY_f – TY_o / TPU_f – TPU_o) kg /kg P.**
7. **Phosphorus agrophysiological efficiency (PAPE) : (GY_f – GY_o / TPU_f – TPU_o) kg/kg P.**
8. **Phosphorus agronomic efficiency (PAE) : (GY_f – GY_o/P_a) kg / kg P**

9. Phosphorus utilization efficiency (PUE) : PPE × PARE (kg /kg P)

Where: GPU and TPU are grain P uptake and total P uptake. TPU_f and TPU_o are total P uptake by grain and straw in the fertilized plot (kg) and the unfertilized plots. P_a is the quantity of P applied (kg). TY_f and TY_o are total yields/fad recorded for the fertilized and the unfertilized. GY_f and GY_o are grain yield of the fertilized crop and unfertilized crop. The calculations were made according to Fageria *et al.* (1997).

Data were statistically analyzed according to Snedecor and Cochran (1981) as a split-split plot design. Analysis was made for each cultivar. Differences between cultivars were compared from the combined of the two seasons using a T-test at 5% level of significance. Treatments means were compared using LSD. In interaction tables, capital and small letters were used to compare rows and column means, respectively, *' and N.S denote the significant and highly significant and the insignificant differences.**

The response equations were calculated according to Snedecor and Cochran (1981) using the orthogonal polynomial tables for significant interactions between factors under study. The significancy of the linear and quadratic components of each of these equations was tested, then the response could be described as linear (first order) or quadratic (second order).

The predicted maximum averages (Y_{max}) which could have been obtained due to the addition of the predicted maximum P level (X_{max}) were calculated according to Neter *et al.* (1990). The predicted optimum grain yield ($Y_{opt.}$) obtained due to the addition of the predicted optimum P level (Xopt.) and the profit obtained due to this addition was calculated according to AbdulGalil *et al.* (2003) using the following equation :

Profit (1) = P [C $(X_{opt.})^2$] in LE

Profit (2) = P (Grain yield without P fertilizer)

Where: profit (1) is gained due to addition of the optimum P level ($X_{opt.}$). Profit (2) is obtained without P fertilization. P is the price of ardab (180 LE). q is the cost of P unit (70 LE). C is the quadratic coefficient of the grain yield response equation.

RESULTS AND DISCUSSION

A) Wheat yield and its attributes

A.1. Plant height and number of spikes/m^2:

A.1.a. Cultivar differences:

In both seasons, Gemmiza 9 had taller plants with larger number of spikes/m^2 than Sakha 93. These differences were significant regarding plant height in the second season and number of spikes/m^2 in the first season. The combined analysis, however, did not detect the significancy of these differences (Table 1).

It seems evident that the superiority of Gemmiza 9 in plant height was not on the expense of tillering and hence the number of spikes /m^2. In the

1

literature, several workers reported significant cultivar differences in yield attributes and yield potentiality (Mowafy, 2002; Allam, 2003; Ali, *et al.,* 2004 and Gafaar, 2007).

A.1.b. Nitrogen level effect:

Doubling the level of added nitrogen to 100 kg N/fad was accompanied by a significant increase in each of plant height and number of spikes/m^2. The role of N in plant elongation and tillering is extesively reported in the literature by Shaaban (2006) and Weber *et al.* (2008) when they increased N level to wheat up to 40 and 75.5 kg N/fad. Also, others got similar response when they added 100 kg N/fad (AbdulGalil *et al.,* 1997 and Abd El-Maaboud *et al.* 2006).

A.1.C. Phosphorus level effect:

Each P increment reflected a significant increase in plant height of the two wheat cultivars in both seasons. This was also true regarding the number of spikes/m^2 except the failure of the 3rd P increment to add a further significant increase in the number of spikes/m^2 of Gemmiza 9 in the first season. However, the combined analysis ascertained the significancy of this P increment where each increase in P level produced a significant increase in both the plant height and the number of spikes/m^2.

It is interesting to note down that Sakha 93 was more responsive to P than Gemmiza 9, regarding plant height. The reverse was true regarding the number of spikes/m^2. Also, the two wheat cultivars were in need to a higher level of P to maximize their plant heights than to maximize the number of spikes/m^2. It is evident from Table (1) that Gemmiza 9 could produce an increment of 77.03 spike/m^2 due to a predicted addition of 52.6 kg P_2O_5/fad compared with 65.60 spikes/m^2 produced by Sakha 93 due to a predicted addition of 53.8 kg P_2O_5 /fad. According to these results, the highest P level tried in this study (60 kg P_2O_5/fad) satisfied the N requirements of the two wheat cultivar in regarding maximizing their tillering and hence the number of spikes/m^2.

Since the soil of the experimental site is sandy and had a poor content of available P (3.4 ppm), wheat responded to each P increment up to the addition of 60 kg P_2O_5/fad. This addition maximized plant height and number of spikes/m^2 in both wheat cultivar but with greater magnitude in Gemmiza 9 than in Sakha 93 cultivar.

The importance of P in enhancing tillering as a determinant of wheat yield was reported by (Davidson and Mchevalier, 1990 and Rodriguez *et al.* 1999). Phosphorus is a limiting factor for growth and tillering (Sato *et al.,* 1996 and Rodriguez *et al.,* 1999). Some authors found significant increase in yield attributes of wheat when P ranged from 13 to 25 kg P_2O_5/fad (AdulGalil *et al.,* 2003; Sarhan, 2004 and El-Mancy and Kotb, 2006).

A.1.d. Phosphorus splitting effect:

It is quite clear from Table (1) that splitting of added P as ½ at sowing and ½ one month later enhanced plant elongation and tillering as well, where the highest averages were recorded. On the other hand, the lowest plant height and number of spikes/m^2 averages were recorded when P was split as ½ at sowing and ½ two months later. This was true in the two wheat cultivars in the two seasons and their combined.

These results clearly indicate that wheat plants were not benefited from delaying the addition of the second split of phosphorus to two months instead of one month after sowing. The full addition at sowing produced taller plants with larger number of spikes/m^2 than the formationed treatment. This indicates the late added P two months after sowing was not efficiently used by wheat plants whereas early added one was more effective as for as elongation and tillering.

Yield and its attributes of wheat are affected by the timing of P application, (Satorre and Slafer, 1999). Also, El-Marsafawy, *et al.* (2001) observed that sesame yield and its attributes were significantly increase when P fertilizer was applied at the second irrigation.

A.1.e. Interaction effect :

The N × P interaction affected significantly plant height of Gemmiza 9 in the first season, and of Sakha 93 in the second season. The combined analysis ascertained this significant effect in only Gemmiza 9. This interaction affected significantly the number of spikes/m^2 of the two wheat cultivars in both seasons and their combined (Table 1-a). The N × S and S × P interactions had different significant effects in the two wheat cultivars. However, the combined analysis detected significant effect of the N × S interaction on plant height and number of spikes/m^2 of Sakha 93 (not presented) and of S × P interaction on plant height of the two wheat cultivars and number of spikes/m^2 of Sakha 93. (Table 1-b)

It is evident from Table (1-a) that the response of either plant height or number of spikes/m^2 to the increase of P level was positive diminishing but with different magnitudes at the two N levels and in the two wheat cultivars. It is quite evident that lower predicted maximum P level was needed to maximize plant height of Gemmiza 9 at the high than at the low N level. This was also true regarding the number of spikes/m^2 of Sakha 93. However, a higher predicted P level was needed to maximize the number of spikes/m^2 of Gemmiza 9 at the high than at the low N level. Therefore in Kasha 93 N and P played a compensating roles whereas in Gemmiza 9 they played a complentry one.

It is evident from Table (1-b) that Gemmiza 9 plant height showed linear response to the increase of P level when added in two splits as in S_2 whereas this response was diminishing in Sakha 93. This diminishing response was observed, also in the number of spikes/m^2 of Sakha 93. In both cases, as in lower P level was needed to maximize plant height and number of spikes/m^2 of Sakha 93 when the second split was given one month instead of two months after sowing (S_2).

A.2. Grain weight/spike and its components :

A.2.a. Cultivar differences :

In both seasons and their combined, Gemmiza 9 had significantly larger number of grains /spike and heavier 1000 grain weight than Sakha 93. This was also true regarding the grain weight/spike but the differences did not reach the level of significance in both seasons and their combined (Table 2).

These results clearly indicate the superiority of Gemmiza 9 over Sakha 93 in all grain yield attributes. Results in Table (1) showed that it had longer plants and larger number of spikes /m^2 than Sakha 93. In the literature, several authors reported significant varietal differences in yield attributes and yield potentiality of wheat (Allam, 2005; Gaballah, 2005-a and El-Sawi *et al.,* 2006).

A.2.b. Nitrogen level effect :

Doubling the level of N to 100 kg N/fad was followed by a significant increase in the grain weight/spike and its two components. This was valid in the two wheat cultivars in the two seasons and their combined with the exception of the difference observed in grain weight /spike of Sakha 93 in the second season where this difference did not reach the level of significance (Table 2).

Similar favourable effect was observed due to the increase of N level on plant height and number of spikes/m^2 (Table 1). Several workers reported significant increase in yield and its attributes due to the increase of N up to 105 kg N/fad (Tawfelies and Tammam, 2005). However, Mowafy (2002), Abdul Galil *et al.* (2003), Haikel and El-Melegy (2005) and Mekail *et al.* (2006) found that this response reached 120 kg N/fad.

A.2.c. Phosphorus level effect :

In the two wheat cultivars, each P increment produced a significant increase in each of the number and weight of grains/spike as well as the 1000-grain weight. This was true in both seasons and their combined (Table 2). In all cases, Gemmiza 9 was more efficient than Sakha 93 in making use of soil phosphorus where it recorded higher averages at the zero P level. This was also true at the rest of P levels up to the addition of 60 kg P_2O_5/fad. However, Sakha 93 was more responsive than Gemmiza 9 to the increase of P level, where it recorded higher maximum response of 0.449 gm in grain weight/spike due to a predicted P addition of 51.8 kg P_2O_5/fad compared with a maximum response of only 0.409 gm recorded by Gemmiza 9 due to a predicted addition of 51.0 kg P_2O_5/fad. Similar magnitude of response could, also be observed in the number of grains/spike and the 1000 grain weight and could account for the varietal response observed herein in the grain weight/spike.

According to these results, the two wheat cultivars were in need for about 52 kg P_2O_5/fad in order to maximize their grain weight/spike. Similar results were reported by AbdulGalil *et al.* (1997), Saleem (2000), Abbas *et al.* (2001)

2

and Kotb (2007) when they increased P level to wheat up to 31. kg P_2O_5. Moreover, Aly (1998) and Attia and Aly (1998) reported that wheat yield and its attributes showed a positive response to P application up to 46.0 kg P_2O_5/fad.

A.2.d. Phosphorus splitting effect:

Splitting of added P had different significant effects on the grain weight/spike and its two components. The number of grains/spike followed the previously observed trend observed in plant height and number of spikes/m^2. The highest grain number was recorded by split addition of P as ½ at sowing and ½ one month later whereas the lowest number was recorded due to delaying the second split to two months after sowing which recorded the heaviest 1000-grain weight and hence the heaviest grain weight/spike.

These results clearly indicate the late added P was more effective on the 1000 grain weight which inturn was more conributing to the grain weight /spike than the grain number. This refers to intra-spike competition for photosynthetas by the larger number of grains/spike produced due to early addition of the second P split one month after sowing. This splitting treatment produced as well larger number of spikes/m^2 than the split addition of P two months after sowing refering to a possible inter-spikes competition. These two intra-plants competitions could account for the decrease observed in the grain weight/spike due to the early addition of the second P split one month after sowing.

A.2.e. Interaction effect :

The N × P interaction affected significantly the grain weight/spike and its components of the two wheat cultivars (Table 2-a). Also, the N × S affected significantly the grain weight/spike of Sakha 93 in the second season and was confirmed by the combined analysis (Table 2-b).

It is evident from Table (2-a) that the grain weight/spike showed quadratic response to the increase of P level. This response was higher at the higher than at the lower P level, where higher predicted grain weight /spike could have been obtained due to the addition of a lower predicted P level. In other words, the increase of N level maximized the response to added P in the two wheat cultivars. This was also observed in the number of grains/spike and the 1000-grain weight and could account for the response observed herein in the grain weight /spike. In the two wheat cultivars only about 47.0 kg P_2O_5/fad were needed to maximize the grain weight /spike at the high N level compared with 60.4 and 57.3 kg P_2O_5/fad needed to maximize this weight at the low N level by Sakha 93 and Gemmeiza9, respectively.

It is evident from Table (2-b) that the late split addition of P at two months after sowing recorded the heaviest grain weight/spike of Sakha 93 at the low N levels. However, when the N level was increased the two P splitting treatments produced at par averages which were higher than that recorded by the full P addition at sowing.

A.3. Grain, straw and total yields/fad and harvest index

A.3.a. Cultivar differences :

In the second season and the combined of the two seasons, Gemmiza 9 recorded significant higher grain yield/fad than Sakha 93. However, the two wheat cultivars did not vary significantly in the straw yield/fad. The superiority of Gemmiza 9 was reflected in harvest index as it recorded higher average than Sakha 93 in the first season and the combined of both seasons (Table 3).

The superiority of Gemmiza 9 in grain yield/fad is rather expected as it had higher number of spikes/m^2 (Table 1) with heavier grain weight/spike (Table 2) than Sakha 93 though the differences did not reach the level of significance in both seasons and their combined except in the number of spikes/m^2 in the first season. In literature, several authors reported significant varietal differences in yield and its potentiality (Mehasen and Mohamed, 2005; Table *et al.,* 2005 and Abd el-Hameed, 2006).

A.3.b. Nitrogen level effect:

Doubling the level of N to 100 kg N/fad was followed by a significant increase in grain yield/fad and harvest index in both seasons and their combined. This was also, true regarding the straw yield/fad with the exception of the insignificancy of differences in the second season (Table 3). This could be attributed to the increase of number of spikes/m^2 (Table 1) and grain weight/spike (Table 2) which could account for the increase observed herein in grain and straw yields/fad and in the harvest index. Under sandy soil conditions, Gaballah (2005-b) got similar results due to additions of N up to 100 kg N/fad. Also, others got similar response when they added 120 kg N/fad (Ashmawy and Abo-Warda, 2002). However, Allam (2003) and Selim (2004) got higher response when they added 125 kg N/fad. Furthermore, Soliman (2000) found similar response, but, to N addition of 180 kg N/fad.

A.3.c. Phosphorus level effect:

Each P increment was followed by a significant increase in grain yield/fad. However, the straw yield/fad showed different trends in the two wheat cultivars and in the two seasons. According to the combined analysis, no further significant increase was obtained in the straw yield/fad of Sakha 93 beyond the addition of 20 kg P_2O_5/fad and in the straw yield/fad of Gemmiza 9 beyond the addition of 40 kg P_2O_5/fad.

According to these results the harvest index was significantly increased with each P increment up to the addition of 60 kg P_2O_5/fad. This clearly indicates that added P promoted dry matter partitioning towards grain filling and hence the grain yield/fad was increased. The results further indicate that the increase of number of spikes/m^2 and grain weight per spike (Tables 1 and 2) due to the increase of P level up to the addition of 60 kg P_2O_5/fad was reflected herein insignificant increase of grain yield/fad. Some workers reported significant increase in yield of wheat due to the increase of P level up to 31.0 kg P_2O_5/fad (Abd-Alla, 2002; Abdel-Hameed, 2005 and

Abd El-Maaboud *et al.,* 2006). Moreover, Hegazi and Hassan (1998) and El-Bana (2000) reported that wheat responded to more addition of P reaching 45 kg P_2O_5/fad.

A.3.d. Phosphorus splitting effect:

In both seasons and their combined addition of P as ½ at sowing and ½ one month later produced the highest grain yield averages whereas delaying the addition of the second split to two months after sowing recorded the lowest ones. This was true in Gemmiza 9 in the two seasons and their combined and in Sakha 93 in the second season and the combined. This was also observed in harvest index (Table 3).

Similar favourable effects were observed in all grain yield attributes due to splitting P partially at sowing and one month later (Tables 1 and 2). El-Marsafawy (2000) noticed that 15.5 P_2O_5/fad application after planting promote the plant root to more interception to the soil and more absorption from P immediately before fixation and hence yield and its attributes were increased.

A.3.e. Interaction effect:

The N × P interaction affected significantly the grain yield/fad as well as harvest index as given in Table (3-a).

In both wheat cultivars the response of grain yield/fad due to the increase of P level was diminishing but with different magnitude at the two N levels. It is evident from Table (3-a) that higher grain yield averages could have been obtained due to the addition of lower predicted P level at the high than at the low N level. In Sakha 93, a maximum predicted grain yield of 10.70 ardab/fad could have be obtained due to the addition of 78.4 kg P_2O_5/fad at the low N level compared with higher yield of 12.18 ardab/fad obtained due to the addition of only 47.1 kg P_2O_5/fad at the high N level. This was also observed in Gemmiza 9 where these yield maximums were 11.15 and 12.68 ardab/fad predicted due to the addition of 61.9 and 46.4 kg P_2O_5/fad, respectively. This effect was also observed in the harvest index indicating that the increase of N level maximized the effect of added phosphorus and hence saved the need of high P addition.

From the economical point of view the results in Table (3-a) show also that the optimum grain yield /fad could be maximized to 11.33 and 12.62 ardab/fad in Sakha 93 and Gemmiza 9 due to the addition of a predicted optimum P level of 40.6 and 40.5 kg P_2O_5/fad, in respective order. These additions could secure a profit of 443.57 LE in Sakha 93 and 489.56 LE in Gemmiza 9. The total profit obtained due to these additions amounted to 2038.4 and 2133.0 LE in the two wheat cultivars, respectively.

According to these results optimum additions of about 40 kg P_2O_5/fad are recommended at the high N level (100 kg/fad) to optimize the grain yield/fad to 11.33 and 12.62 ardab/fad in Sakha 93 and Gemmiza 9, respectively. However, in order to maximize the grain yield to 12.18 and 12.68 ardab/fad additions of about 47 kg P_2O_5/fad are recommended.

It is interesting to note down that the additions which maximized the grain yield/fad are the same which maximized the grain weight/spike in the two wheat cultivars (Table 2-a). These additions maximized as well the harvest index (Table 3-a).

B. Phosphorus uptake and efficiency attributes :

B.1. Total phosphorus uptake and translocation and recovery efficiency

B.1.a. Cultivar differences

The two wheat cultivars varied significantly in the total P uptake (TPU) where Gemmiza 9 had higher uptake average than Sakha 93. However, no significant varietal differences could be detected in P translocation efficiency (PTE) or P apparent recovery efficiency (PARE).

These results clearly indicate that Gemmiza 9 had higher capacity than Sakha 93 in uptaking phosphorus. This could be observed in the high capacity of Gemmiza 9 in recovering 34.56% from added P fertilizer compared with only 28.87% recovered by Sakha 93 though the differences in this recovery did not reach the level of significance (Table 4). The results further indicate that about 50% of uptaken phosphorus was translocated to wheat grains in the two wheat cultivars.

B.1.b. Nitrogen level effect :

Doubling the level of N to 100 kg N/fad was accompanied by a significant increase in each of TPU and PTE of the two wheat cultivars. This was also observed in the PARE but the difference did not reach the level of significance in Gemmiza 9 (Table 4).

These results could be attributed to the increase of total yield/fad due to doubling the level of N addition (Table 3). The increase of PTE indicates the more partition of P towards grain filling. Moreover, the increase of PARE due to the increase of N level, indicate that added N might have had increased root extension where more root surface was served for P uptake from added phosphorus.

B.1.c. Phosphorus level effect:

It is evident from Table (4) that each P increment was followed by a significant increase in the TPU where Gemmiza 9 was more responsive than Sakha 93 in this respect. This response amounted to 7.046 kg P/fad which could be obtained due to a predicted addition of 68.8 kg P_2O_5/fad in Gemmiza 9 compared with 6.286 kg P/fad obtained due to the addition of 76.9 kg P_2O_5/fad in Sakha 93.

The PTE of Sakha 93 showed linear response to the increase of P level, but this response was quadratic in Gemmiza 9. The PTE of Gemmiza 9 could be maximized due to the addition of 61.2 kg P_2O_5 /fad. In both wheat cultivars, the PARE showed significant diminishing decrease with each P increment.

These results clearly indicate that wheat plants could make use of soil phosphorus. It was evident that without P addition, Sakha 93 and Gemmiza 9,

4

could uptake 6.81 and 7.67 kg P/fad, in respective order, However, with each P increment, the two wheat cultivars, could increase this uptake but diminishingly. This diminished increase in P uptake could account to the significant decrease of PARE due to the increase of P level.

B.1.d. Phosphorus splitting effect:

Splitting of added P as ½ at sowing and ½ one month later (S_2) recorded the highest TPU, PTE and PARE averages. However, addition of the second split two instead of one month after sowing (S_3) recorded the lowest averages. This was true in the two wheat cultivars (Table 4).

These results again reflected the efficiency of early top dressed P than late to P dressed one as far as P uptake and translocation to grain and recovery from fertilizer phosphorus. The results further account for the increase of all growth and yield attributes due to this early P split addition (Tables 1 and 2).

B.1.e. Interaction effect:

According to the combined analysis, the N × P interaction affected significantly the TPU of the two wheat cultivars and the PTE of Gemmiza 9 and PARE of Sakha 93 (Table 4-a). Also, the N × S and S × P interactions affected significantly the TPU and PARE of the two wheat cultivars (Tables 4-b and 4-c, respectively).

It is evident from Table (4-a) that the TPU was significantly increased with each P increment but with different magnitudes at the two N levels. This response was diminishing at the high N level in the two wheat cultivars. Also, the increase of N level played a significant role, particularly in Gemmiza 9, in saving the additions of phosphorus, where lower P level was needed to maximize the TPU at the high than at the low N level.

It is evident also from (Table 4-a) that the PTE of Gemmiza 9 showed linear response at the low N level but quadratic at the high N level. Addition of a predicted P level of only 45.4 kg P_2O_5/fad could have had maximized this efficiency to 51.77% at the high N level.

Finally results in Table (4-a) indicated that the PARE of Sakha 93 showed differential response to the increase of P level at the two N levels. This efficiency continued to decrease with each P increment at the high N level, but no further decrease was observed beyond the addition of 40 kg P_2O_5/fad at the low N level.

Regarding the N × S interaction results in (Table 4-b) showed that both the highest TPU and PARE averages were recorded when P was split partly at sowing and one month later (S_2) whereas the lowest averages were recorded when the 2nd split was delayed to two months after sowing (S_3). This was true at the two N levels and in the two wheat cultivars but with more pronounced effect at the high than at the low N level and in Gemmiza 9 than in Sakha 93. The total uptake was maximized to 17.83 kg P/fad (42.61 kg P_2O_5/fad) in Gemmiza 9 compared to only 15.85 kg P/fad (37.66 kg P_2O_5/fad) in Sakha 93 at the high N level, when P was added as ½ at sowing and ½ one month later.

This was also observed in the PARE which was maximized to 52.07 and 59.09% in Sakha 93 and Gemmiza 9, respectively.

These results clearly indicate that doubling the level of N to 100 kg N/fad increased the efficiency of wheat plants in recovering added phosphorus. This recovery amounted to more than 50% when P was split added partly at sowing and one month later but was minimized to about 20% when the second split was delayed to two months after sowing.

It is evident from Table (4-c) that each P increment was followed by a significant linear increase in the total P uptake in the two wheat cultivars but with higher magnitude in S_2 than in S_1 or S_3. Therefore PARE was significantly decreased with each P increment in this P splitting treatment.

These results clearly indicate that the early addition of the second P split at one month after sowing had maximized the total uptake of P and its recovery from added P fertilizer. This addition coincided with the active crown root stage as well as the early tillering both of which might have had enhanced the P uptake as a total and specifically from added P fertilizer. The decrease of PARE with the increase of P addition indicates a diminishing increase of TPU.

B.2. Phosphorus physiological, agrophysiological, utilization and agronomic attributes :

Results in Table (5) show the effect of N level, P level and splitting of the different P levels on Phosphorus physiological efficiency (PPE), Phosphorus agrophysiological efficiency (PAPE), Phosphorus utilization efficiency (PUE) and Phosphorus agronomic efficiency (PAE) in the two wheat cultivars according to the combined analysis.

B.2.a. Cultivar differences:

No significant cultivar differences could be detected in any of the abovementioned P efficiency attributes though Gemmiza 9 had, in most cases higher averages than Sakha 93. Similar insignificant cultivar differences were mentioned regarding the PTE and PARE (Table 4) and could account for the insignificancy of cultivar differences observed herein.

B.2.b. Nitrogen level effect:

Doubling the level of N decreased the PPE in the two wheat cultivars, with significant effect in Gemmiza 9. However, the PAPE was not significantly affected by the increase N level in the two wheat cultivars. However, the PUE of Gemmiza 9 was decreased whereas the PAE of Sakha 93 was increased due to the increase of N level (Table 5). The significant decrease of PPE and PUE of Gemmiza 9 due to doubling the level of N could be attributed to a significant increase in P uptake caused by this N increment (Table 4). However, the significant increase of PAE of Sakha 93 due to the increase of N level indicating that this N increment was efficiently served in building up the grain yield.

This effect was also evident in Gemmiza 9 but with less magnitude. In other words Gemmieza 9 was more efficient than Sakha 93 in serving the low N level in building up the grain yield whereas, Sakha 93 was more responsive in serving the increase of N level in this respect.

B.2.c. Phosphorus level effect:

Each P increment caused a significant decrease in each of PPE, PAPE, PUE and PAE in the two wheat cultivars. The response of these P efficiency attributes was diminishing in the two wheat cultivars (Table 5) and was also observed in PARE (Table 4) which could account for the results obtained herein. The diminishing increase in total P uptake due to the increase of P level could also account for the decrease observed herein in each of PPE, PAPE, PUE and PAE.

B.2.d. Phosphorus splitting effect:

The highest PPE average was recorded in the two wheat cultivars when P was split added as ½ at sowing and ½ two months later whereas lowest one was recorded due to the split addition of P as ½ at sowing and ½ one month later. This was also, observed in PAPE with more clear trend in the two wheat cultivars. The reverse was true regarding both the PUE and PAE where the highest averages were recorded for the addition of P as ½ at sowing and ½ one month later.

Therefore, the PUE and PAE are more meaningful from the efficiency fertilization point of view. PUE expresses the amount of biomass yield whereas, PAE expressed the amount of grain yield produced per kg of added P. Both P efficiency attributes, followed the trends of total P uptake and the P apparent recovery efficiency and hence clearly indicate that split addition of P as ½ at sowing and ½ one month later promoted the uptake of P and its recovery from added P which in turn increased its utilization in building the wheat biomass and finally building the wheat grain yield per kg of added phosphorus.

B.2.e. Interaction effect

The N × P interaction affected significantly the PPE of Gemmiza 9 and he PAPE, PUE and PAE of the two wheat cultivars (Table 5-a). The N × S interaction affected significantly the PUE of the two cultivars (5-b) finally the P × S interaction affected significantly the PUE and PAE of the two wheat cultivars (Table 5-c).

It is evident from Table (5-a) that all the P efficiency attributes were decreased with the increase in P level but with higher magnitude at the high than at the low N level. These decreases could be attributed to the diminishing increase in total P uptake with each P increment (Table 4-a).

It is evident from Table (5-b) that the PUE was maximized in the two wheat cultivars when P was given as ½ at sowing and ½ one month later at the two N levels. However, PUE was significantly decreased when the level of N was increased in Gemmiza 9 and was at par in Sakha 93. The decrease of PUE due to the increase of N level could be attributed to the high P uptake (Table 4-b).

It is evident from Table (5-c) that each P increment caused a significant decrease in each of PUE and PAE of the two wheat cultivars but with different magnitudes for the different P splitting treatments. According to the response equations, this decrease was of higher magnitude when P was given as ½ at sowing and ½ one month later and in Gemmiza 9 than in Sakha 93. This deferential response was also observed in the total P uptake and PARE (Table 4-c) and could account for the results obtained herein.

From these results it could be concluded that two of the P fertilization attributes i.e. the PUE and PAE could be served to express the efficiency of P recovery and its use in building the total biomass yield and in turn the final grain yield. The PUE is the product of PPE and PARE and hence expresses the efficiency of added phosphorus in building the wheat biomass. also, the PAE, directly, expresses the efficiency of added P in building up the grain yield. Both of these efficiency attributes were decreased with each P increment, certainly, due to the diminishing increase of biomass and grain yields. However, when the P splitting treatments were evaluated, through these two P efficiency attributes, they ascertained the superiority of the split addition of P as ½ at sowing and ½ one month later as they were maximized due to this addition.

CONCLUSION

The significant N × P interactions indicated that addition of P could be optimized at 40.6 kg P_2O_5/fad through the increase of N level to 100 instead of 50 kg N/fad where the two nutrients, played compensatory roles in all growth and yield attributes. Finally, the S × P interaction indicated the possibility of minimizing P addition through it's application as ½ at sowing and ½ one month later. This was ascertained by the high total P uptake and its agronomic, as well as, utilization efficiency.

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تأثير مستوى النيتروجين وتجزئ مستويات مختلفة من الفوسفور على محصول صنفين من القمح ومؤشرات كفاءة استخدام الفوسفور باستخدام الرى بالرش فى الأراضى الرملية

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الملخص العربي

أجريت هذه الدراسة خلال موسمى ٢٠٠٤/٢٠٠٥ ، ٢٠٠٥/٢٠٠٦ بمحطة التجارب الزراعية بالخطارة التابعة لكلية الزراعة – جامعة الزقازيق وذلك لدراسة استجابة صنفان من القمح (سخا ٩٣ ، جميزة ٩) لمستويين من النيتروجين (٥٠ ، ١٠٠ كجم ن/فدان) ، أربعة مستويات من الفوسفور (كنترول ، ٢٠ ، ٤٠ ، ٦٠ كجم فو٢أ٥/فدان) وثلاث معاملات لتجزئ الفوسفور (عند الزراعة ، ½ عند الزراعة + ½ بعد شهر من الزراعة ، ½ عند الزراعة + ½ بعد شهرين من الزراعة) وتم تتبع تأثير المعاملات تحت الدراسة على المحصول ومساهماته بالإضافة إلى الفوسفور الممتص ومؤشرات كفاءة استخدامه ويمكن تلخيص أهم النتائج المتحصل عليها كما يلى :

- تفوق الصنف جميزة ٩ على الصنف سخا ٩٣ فى محصول الحبوب / فدان بفضل تفوقه فى كل من ارتفاع النبات (موسم ثانى) ، عدد السنابل / م٢ (موسم أول) ، عدد الحبوب بالسنبلة (تجميعى) ، وزن ١٠٠٠ حبة (تجميعى) ، دليل الحصاد (تجميعى) الكمية الكلية للفوسفور الممتص (تجميعى) بينما لم يختلف الصنفان فى كل من وزن حبوب السنبلة ، محصول القش / فدان ، كفاءة انتقال الفوسفور ، الكفاءة الظاهرية لإسترجاع الفوسفور ، الكفاءة الفسيولوجية للفوسفور ، الكفاءة الفسيومحصولية للفوسفور ، كفاءة استخدام الفوسفور والكفاءة المحصولية للفوسفور بالرغم من تسجيل جميزة ٩ أعلى القيم عن سخا ٩٣.
- مضاعفة النيتروجين إلى ١٠٠ كجم ن/ف أدى لزيادة معنوية فى كل من ارتفاع النبات ، عدد السنابل/م٢ ، عدد ووزن حبوب السنبلة ، وزن ١٠٠٠ حبة ، محصول القش/ فدان ، دليل الحصاد ، الكمية الكلية للفوسفور الممتص ، كفاءة انتقال الفوسفور ، الكفاءة الظاهرية

لإسترجاع الفوسفور والكفاءة المحصولية للفوسفور بينما انخفض كل من الكفاءة الفسيولوجية للفوسفور وكفاءة استخدام الفوسفور.

- أدى إضافة الفوسفور وزيادة معدل الإضافة حتى ٦٠ كجم فو٢أ٥ لزيادة معنوية فى محصول الحبوب/فدان ومعظم مساهماته ولكن انخفض معنوياً كل من الكفاءة الظاهرية لإسترجاع الفوسفور ، الكفاءة الفسيولوجية للفوسفور ، الكفاءة الفسيومحصولية للفوسفور ، كفاءة استخدام الفوسفور والكفاءة المحصولية للفوسفور.
- أوضح التحليل التجميعى للموسمين أن إضافة الفوسفور بنظام نصف الكمية عند الزراعة ونصف الكمية عند شهر من الزراعة أدى للحصول على أعلى المتوسطات فى كل من ارتفاع النبات ، عدد السنابل /م٢ ، عدد حبوب السنبلة ، محصول الحبوب / فدان ، دليل الحصاد ، الكمية الكلية للفوسفور الممتص ، كفاءة انتقال الفوسفور ، الكفاءة الظاهرية لإسترجاع الفوسفور ، كفاءة استخدام الفوسفور والكفاءة المحصولية للفوسفور بينما أدى تأخير إضافة الدفعة الثانية من الفوسفور حتى شهرين من الزراعة للحصول على أعلى المتوسطات فى كل من وزن ١٠٠٠ حبة ، وزن حبوب السنبلة ، الكفاءة الفسيولوجية للفوسفور والكفاءة الفسيومحصولية للفوسفور.
- أوضحت نتائج تداخل الفعل بين مستويات النيتروجين والفوسفور أنه يمكن معظمة محصول الحبوب/فدان إلى ١١.٣٣ ، ١٢.٦٢ أردب/ف لسخا ٩٣ ، جميزة ٩ بإضافة أمثل مستوى من الفوسفور وهو ٤٠.٦ ، ٤٠.٥ كجم فو٢أ٥/ف على التوالى وهذه الإضافة تحقق عائد ٤٤٣.٥٧ للصنف سخا ٩٣ ، ٤٨٩.٩٣ جنيه للصنف جميزة ٩ بينما كان العائد الكلى نتيجة هذه الإضافة حوالى ٢٠٣٨.٤ ، ٢١٣٣ جنيه للصنفين على الترتيب. وتؤكد نتائج هذه الدراسة على أن زيادة معدل التسميد النيتروجينى أفاد فى خفض مستوى الفوسفور المضاف حيث لعبا دوراً تعويضياً وكذلك أفاد تجزئ الفوسفور وإضافته مناصفة عند الزراعة وبعدها بشهر فى زيادة كفاءة هذه الإضافة ومن ثم معظمة نمو ومحصول صنفى القمح تحت ظروف الأراضى الرملية وباستخدام الرى بالرش.

Table (1): Plant height and number of spike/m^2 of the two wheat cultivars as affected by N levels and splitting of different levels of phosphorus in the two seasons and their combined.

Main effects and interactions	Plant height (cm)						No. of spikes/m^2					
	First season		Second season		Combined		First season		Second season		Combined	
	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9
Nitrogen levels effect : (N)												
50 kg N/fd	81.42	83.73	82.35	84.54b	81.89	84.14	246.8	268.4	247.9	275.6	247.3	272.0
100 kg N/fad	86.00	89.11	86.77	88.50a	86.39	88.81	283.5	294.2	293.2	300.5	288.3	297.3
F. test	**	**	**	**	**	**	**	**	**	**	**	**
Phosphorus levels effect : (P)												
Check	73.47d	79.93d	78.98d	80.14d	76.22d	80.04d	216.0d	220.9c	217.9d	230.5d	216.9d	225.7d
20 kg P_2O_5/fad	79.62c	85.14c	83.46c	85.44c	81.54c	85.30c	261.2c	270.5b	260.2c	277.8c	260.7c	274.7c
40 kg P_2O_5/fad	86.82b	87.46b	85.49b	87.62b	86.16b	87.54b	272.5b	294.9a	279.8b	300.6b	276.1b	297.7b
60 kg P_2O_5/fad	88.10a	88.83a	86.60a	88.62a	87.35a	88.72a	278.2a	298.7a	289.2a	304.8a	283.7a	301.8a
F. test	**	**	**	**	**	**	**	**	**	**	**	**
Maximum response	15.76	8.70	7.50	8.33	11.52	8.50	61.83	78.91	70.10	75.11	65.60	77.03
Maximum X	71.80	60.2	59.8	55.8	66.8	57.8	50.0	52.60	58.2	52.8	53.8	52.6
Phosphorus splitting effect : (S)												
S_1 (at sowing)	85.42b	87.48b	85.08b	87.01b	85.25b	87.25b	273.2b	286.7b	277.3b	296.8b	275.3b	291.8b
S_2 (½ at sowing + ½ one month later)	87.19a	89.03a	86.71a	89.20a	86.95a	89.12a	278.3a	294.7a	286.3a	302.5a	282.3a	298.6a
S_3 (½ at sowing + ½ two months later)	81.92c	84.91c	83.76c	85.48c	82.84c	85.20c	260.4c	282.8b	265.5c	283.9c	262.9c	283.3c
F. test	**	**	**	**	**	**	**	**	**	**	**	**
Interaction effect :												
N × P	NS	**	*	NS	NS	**	**	*	**	**	**	**
N × S	**	**	NS	NS	**	NS	NS	NS	**	NS	**	NS
S × P	**	**	NS	NS	**	**	NS	NS	*	NS	*	NS
Cultivar differences :												
Sakha 93	83.71		84.56		84.14		265.2		270.5		267.8	
Gemmiza 9		86.42		86.52		86.47		281.3		288.0		284.7
T. test	NS		*		NS		*		NS		NS	

Table (1-a) : Plant height and No. of spikes/m^2 as affected by N × P interaction, as well as, response equations and predicted maximum (Y_{max}) and P level (X_{max}) (combined).

N level	P levels (kg P_2O_5/fad)				Response equation	Y_{max}	X_{max}
kgN/fad	0	20	40	60	= a + bx – cx^2		Kg P_2O_5/fad
				Plant height (cm)			
				Gemmiza 9			
	D	C	B	A			
50	77.41 b	82.63 b	85.09 b	86.94 b	77.52+ 5.634x – 0.843 x^2	86.93	66.83
	C	B	A	A			
100	82.67 a	87.96 a	90.00 a	90.51 a	82.62 + 6.906x – 1.42 x^2	91.02	48.65
				Number of spikes/m^2			
				Sakha 93			
	D	C	B	A			
50	187.06 b	238.4 b	255.1 b	268.6 b	188.6 + 54.57x – 9.475 x^2	267.2	57.60
	C	B	A	A			
100	246.9 a	282.9 a	297.1 a	298.8 a	247.4 + 42.72x – 8.575 x^2	300.6	49.82
				Gemmiza 9			
	D	C	B	A			
50	214.5b	266.2 b	281.3 b	287.8 b	215.9 + 57.40x – 11.30 x^2	288.8	50.8
	C	B	A	A			
100	236.9 a	282.2 a	314.2 a	315.8 a	236.1 + 59.65x – 10.93 x^2	317.5	54.6

Table (1-b) : Plant height and No. of spikes/m^2 as affected by S × P interaction, as well as, response equations and predicted maximum (Y_{max}) and P level (X_{max}) (combined).

P splitting	P levels (kg P_2O_5/fad)			Response equation = $a + bx - cx^2$	Y_{max}	X_{max} (kg P_2O_5 /fad)
	20	40	60			
				Plant height (cm)		
				Sakha 93		
	C	B	A			
S_1	81.10 b	86.87 b	87.80 b	$81.10 + 8.19x - 2.42 x^2$	88.03	53.84
	C	B	A			
S_2	83.53 a	88.04 a	89.30 a	$83.53 + 6.14x - 1.63 x^2$	89.31	57.67
	C	B	A			
S_3	79.99 c	83.57 c	84.97 c	$79.99 + 4.67x - 1.09 x^2$	84.99	62.84
				Gemmiza 9		
	C	B	A			
S_1	85.33 b	87.77 b	88.65 b	$85.33 + 3.22x - 0.78 x^2$	87.50	61.28
	C	B	A			
S_2	86.88 a	89.15 a	91.33 a	$86.88 + 2.315x$	-	-
	C	B	A			
S_3	83.68 c	85.72 c	86.19 c	$83.68 + 2.83x - 0.79 x^2$	86.2	55.82
				Number of spikes/m^2		
				Sakha 93		
	C	B	A			
S_1	261.3 b	278.6 b	285.8 b	$261.3 + 22.35x - 5.05 x^2$	286.0	64.26
	C	B	A			
S_2	267.9 a	285.4 a	293.6 a	$267.9 + 22.15x - 4.65 x^2$	294.3	67.63
	C	B	A			
S_3	252.8 c	264.3 c	271.8 c	$252.8 + 13.5x - 2.00 x^2$	275.6	87.50

Table (2): Number of grains/spike, 1000-grain weight and grain weight /spike of the two wheat cultivars as affected by N levels and splitting of different levels of phosphorus in the two seasons and their combined.

Main effects and interactions	Number of grains/spike						1000-grain weight (gm)						Grain weight /spike					
	First season		Second season		Combined		First season		Second season		Combined		First season		Second season		Combined	
	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9
Nitrogen levels effect : (N)																		
50 kg N/fd	34.40	37.47	34.45	37.27	34.43	37.37	35.18	36.00	34.57	35.66	34.88	35.83	1.582	1.612	1.520	1.596	1.552	1.605
100 kg N/fad	37.31	39.78	36.95	39.73	37.13	39.76	38.71	40.37	37.98	40.03	38.35	40.20	1.792	1.818	1.717	1.752	1.759	1.788
F. test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	NS	**	**	**
Phosphorus levels effect : (P)																		
Check	28.95d	31.69d	28.73d	31.40d	28.84d	31.54d	30.18d	31.83d	29.11d	30.56d	29.65d	31.24d	1.293d	1.373d	1.306d	1.376d	1.303d	1.376d
20 kg P_2O_5/fad	34.53c	37.25c	34.29c	37.25c	34.41c	37.29c	35.51c	36.69c	35.07c	36.48c	35.29c	36.59c	1.668c	1.683c	1.557c	1.635c	1.615c	1.660c
40 kg P_2O_5/fad	37.28b	40.16b	37.26b	39.93b	37.30b	40.04b	38.51b	39.65b	37.81b	39.32b	38.16b	39.49b	1.743b	1.773b	1.678b	1.725b	1.712b	1.751b
60 kg P_2O_5/fad	38.00a	40.77a	37.88a	40.62a	37.94a	40.70a	39.07a	40.34a	38.34a	40.13a	38.71a	40.23a	1.780a	1.804a	1.731a	1.760a	1.757a	1.784a
F. test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Maximum response	9.06	9.15	9.21	9.23	9.15	9.18	8.99	8.57	9.32	9.57	9.16	9.02	0.492	0.433	0.421	0.381	0.449	0.409
Maximum X	54.6	54.4	54.6	53.4	54.6	53.8	55.0	57.4	52.4	54.6	53.8	56.0	48.2	49.8	58.0	52.2	51.8	51.0
Phosphorus splitting effect : (S)																		
S_1 (at sowing)	36.76b	39.81b	36.46b	39.48b	36.61b	39.65b	37.03c	38.06c	36.33c	38.01c	36.68c	38.03c	1.663c	1.626b	1.550c	1.602c	1.608c	1.616c
S_2 (½ at sowing + ½ one month later)	37.53a	40.29a	37.29a	39.96a	37.41a	40.13a	37.78b	39.03b	37.22b	38.66b	37.50b	38.84b	1.725b	1.789a	1.657b	1.723b	1.693b	1.758b
S_3 (½ at sowing + ½ two months later)	35.57c	38.07c	35.68c	38.44c	35.63c	38.26c	38.28a	39.60a	37.67a	39.27a	37.98a	39.44a	1.804a	1.844a	1.760a	1.796a	1.783a	1.822a
F. test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Interaction effect :																		
N × P	**	NS	*	*	**	**	**	**	*	**	**	*	**	**	**	NS	**	**
N × S	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	**	NS
S × P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivar differences :																		
Sakha 93	35.85		35.70		35.78		36.94		36.28		36.61		1.687		1.621		1.655	
Gemmiza 9		38.62		38.50		38.57		38.19		37.85		38.02		1.715		1.683		1.696
T. test	*		*		*		*		*		*		NS		NS		NS	

Table (2-a) : The grain weight /spike and its two component as affected by N × P interaction, as well as, response equations and predicted maximum (Y_{max}) and P level (X_{max}) (combined).

N level kgN/fad	P levels (kg P_2O_5/fad) 0	20	40	60	Response equation = a + bx – cx^2	Y_{max}	X_{max} (Kg P_2O_5/fad)
				No. of grains /spike			
				Sakha 93			
	D	C	B	A			
50	26.98 b	32.94 b	35.89 b	36.93 b	27.04 + 6.97x – 1.23 x^2	36.91	56.67
	C	B	A	A			
100	30.70 a	35.89 a	38.70 a	38.96 a	30.69 + 6.45x – 1.23 x^2	39.15	52.40
				Gemmiza 9			
	D	C	B	A			
50	30.38 b	35.94 b	38.78 b	39.72 b	30.42 + 6.57x – 1.16 x^2	39.72	56.64
	C	B	A	A			
100	32.71 a	38.65 a	41.30 a	41.68 a	32.76 + 7.13x – 1.39 x^2	41.90	51.29
				1000-grain weight (gm)			
				Sakha 93			
	D	C	B	A			
50	28.30 b	33.29 b	36.36 b	37.18 b	28.28 + 6.099x – 1.043 x^2	37.20	58.48
	C	B	A	A			
100	30.99 a	37.28 a	39.97 a	40.24 a	31.05 + 7.559x – 1.505 x^2	40.54	50.23
				Gemmiza 9			
	D	C	B	A			
50	29.77 b	34.27 b	36.95 b	38.30 b	29.80 + 5.190x – 0.788 x^2	38.35	65.86
	C	B	A	A			
100	32.72 a	38.91 a	42.03 a	42.17 a	32.73 + 7.685x – 1.513 x^2	42.49	50.79
				Grain weight /spike (gm)			
				Sakha 93			
	D	C	B	A			
50	1.223 b	1.492 b	1.598 b	1.675 b	1.230 + 0.290x – 0.049 x^2	1.668	60.42
	C	B	A	A			
100	1.383 a	1.738 a	1.826 a	1.839 a	1.392 + 0.404x – 0.086 x^2	1.866	46.98
				Gemmiza 9			
	D	C	B	A			
50	1.285 b	1.558 b	1.648 b	1.717 b	1.293 – 0.292x – 0.051 x^2	1.711	57.25
	C	B	A	A			
100	1.468 a	1.763 a	1.855 a	1.852 a	1.474 + 0.348x – 0.075 x^2	1.878	46.40

Table (2-b): Grain weight /spike of Sakha 93 as affected by N × S interaction (combined).

N level (kgN/fad)	Splitting of phosphorus S_1	S_2	S_3
	Grain weight /spike		
	Sakha 93		
	C	B	A
50	1.488 b	1.583 b	1.695 b
	B	A	A
100	1.729 a	1.803 a	1.871 a

Table (3): Grain and straw yields/fad and harvest index of the two wheat cultivars as affected by N levels and splitting of different levels of phosphorus in the two seasons and their combined.

Main effects and interactions	Grain yield (ardab/fad)						Straw yield (ton/fad)						Harvest index (%)					
	First season		Second season		Combined		First season		Second season		Combined		First season		Second season		Combined	
	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9
Nitrogen levels effect : (N)																		
50 kg N/fd	9.34	9.95	9.54	10.23	9.45	10.10	2.717	2.708	2.646	2.730	2.682	2.719	33.92	35.39	34.96	35.83	34.44	35.61
100 kg N/fad	11.41	11.81	11.47	11.94	11.44	11.88	2.845	2.852	2.808	2.805	2.827	2.829	37.46	38.20	37.90	38.90	37.68	38.55
F. test	**	**	**	**	**	**	**	**	NS	NS	**	**	**	**	**	**	**	**
Phosphorus levels effect : (P)																		
Check	7.79 d	7.95d	8.11d	8.32d	7.95d	8.13d	2.688c	2.538c	2.609	2.603c	2.649b	2.571c	30.20d	31.86d	31.70d	32.26d	30.95d	32.06d
20 kg P_2O_5/fad	10.12c	10.56c	10.04c	10.77c	10.09c	10.67c	2.770b	2.749b	2.711	2.727b	2.741a	2.738b	35.27c	36.41c	35.54c	37.08c	35.41c	36.75c
40 kg P_2O_5/fad	10.70b	11.32b	10.88b	11.51b	10.79b	11.41b	2.784ab	2.825a	2.744	2.802ab	2.764a	2.814a	36.45b	37.47b	37.17b	38.05b	36.81b	37.76b
60 kg P_2O_5/fad	11.16a	11.74a	11.39a	11.91a	11.28a	11.83a	2.821a	2.847a	2.765	2.829a	2.793a	2.838a	37.18a	38.16a	38.14a	38.66a	37.66a	38.41a
F. test	**	**	**	**	**	**	**	**	NS	**	**	**	**	**	**	**	**	**
Maximum response	3.27	3.72	3.20	3.53	3.22	3.63	0.128	0.309	-	0.225	0.138	0.267	6.89	6.21	6.30	6.36	6.53	6.29
Maximum X	52.8	52.2	60.0	52.4	55.8	52.4	68.2	51.2		61.2	58.8	54.4	50.2	50.6	59.2	49.2	53.8	50.0
Phosphorus splitting effect : (S)																		
S_1 (at sowing)	10.75a	11.26b	10.80b	11.40b	10.78b	11.33b	2.795	2.832a	2.733	2.783	2.763	2.808a	36.47a	37.24b	37.10b	37.97b	36.79b	37.61b
S_2 (½ at sowing + ½ one month later)	11.00a	11.80a	11.38a	11.87a	11.19a	11.84a	2.818	2.875a	2.773	2.807	2.796	2.841a	36.83a	38.01a	38.01a	38.75a	37.42a	38.38a
S_3 (½ at sowing + ½ two months later)	10.24b	10.57c	10.13c	10.92c	10.19c	10.75c	2.763	2.713b	2.714	2.768	2.739	2.741b	35.59b	36.78b	35.74c	37.07c	35.67c	36.93c
F. test	**	**	**	**	**	*	NS	**	NS	NS	NS	**	**	**	**	**	**	**
Interaction effect :																		
N × P	*	*	**	**	**	**	NS	**	NS	NS	NS	NS	**	**	**	**	**	**
N × S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
S × P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivar differences :																		
Sakha 93	10.37		10.51		10.44		2.781		2.727		2.754		35.69		36.43		36.06	
Gemmiza 9		10.88		11.09		10.99		2.780		2.768		2.774		36.80		37.36		37.08
T. test	NS		*		*		NS		NS		NS		*		NS		*	

Table (3-a) : Grain yield and harvest index of the two wheat cultivars as affected by N × P interaction, as well as, response equations and predicted maximum and optimum yields and the expected profit (combined).

N level	P levels (kg P_2O_5/fad)				Response equation	Y_{max}	$Y_{opt.}$	Kg P_2O_5/fad		Profit LE		
kgN/fad	0	20	40	60	= a + bx – cx^2			X_{max}	$X_{opt.}$	Pr_1	Pr_2	total
					Grain yield (ardab/fad)							
					Sakha 93							
	D	C	B	A								
50	7.12 b	8.85 b	9.73 b	10.54 b	$7.16 + 1.804x – 0.23 x^2$	10.70	9.33	78.4	61.4	392.74	1288.8	1681.5
	C	B	A	A								
100	8.78 a	11.33 a	11.86 a	12.02 a	$8.86 + 2.819x – 0.598 x^2$	12.18	11.33	47.1	40.6	443.57	1594.8	2038.4
					Gemmiza 9							
	D	C	B	A								
50	7.24 b	9.54 b	10.51 b	11.20 b	$7.29 + 2.494x – 0.403 x^2$	11.15	11.05	61.9	52.28	495.7	1312.2	1807.9
	C	B	A	A								
100	9.03 a	11.80 a	12.33 a	12.46 a	$9.13 + 3.060x – 0.660 x^2$	12.68	12.62	46.4	40.50	489.56	1643.4	2133.0
					Harvest index (%)							
					Sakha 93							
	D	C	B	A								
50	29.54 b	33.27 b	35.06 b	36.62 b	$29.63 + 3.932x – 0.543 x^2$	36.75		72.41				
	C	B	A	A								
100	32.36 a	37.55 a	38.57 a	38.70 a	$32.53 + 5.799x – 1.265 x^2$	39.18		45.84				
					Gemmiza 9							
	D	C	B	A								
50	30.44 b	34.72 b	36.34 b	37.50 b	$30.55 + 4.62x – 0.780 x^2$	37.39		59.23				
	B	A	A	A								
100	33.68 a	38.77 a	39.18 a	39.33 a	$33.89 + 5.46x – 1.240 x^2$	39.90		44.03				

$+pr_1$: Gained due to addition of × opt = P $[(C (× opt.)^2]$ $+pr_2$: obtained without P fertilization

Table (4): Total P uptake, P translocation efficiency and P apparent recovery efficiency of the two wheat cultivars as affected by N levels and splitting of different levels of phosphorus in combined analysis.

Main effects and interactions	Total P uptake (kg P/fad) TPU		P translocation efficiency (%) (PTE)		P apparent recovery efficiency (%) (PARE)	
	Combined		Combined		Combined	
	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9
Nitrogen levels effect : (N)						
50 kg N/fd	9.65	11.31	46.04	46.56	25.52	31.92
100 kg N/fad	12.37	13.99	49.77	50.269	32.22	37.21
F. test	**	**	**	**	*	NS
Phosphorus levels effect : (P)						
Check	6.81 d	7.67 d	44.62 d	43.99 c	-	-
20 kg P_2O_5/fad	9.99 c	11.53 c	46.78 c	47.49 b	36.45 a	44.27 a
40 kg P_2O_5/fad	11.48 b	13.30 b	48.32 b	49.13 a	26.71 b	32.28 b
60 kg P_2O_5/fad	12.96 a	14.78 a	49.72 a	50.08 a	23.45 c	27.14 c
F. test	**	**	**	**	**	**
Maximum response	6.286	7.046	Linear	5.980	13.00	17.35
Maximum X	76.9	68.8		61.2	60.1	65.0
Phosphorus splitting effect : (S)						
S_1 (at sowing)	10.73 b	12.23 b	48.71 b	49.27 b	23.89 b	28.24 b
S_2 (½ at sowing + ½ one month later)	14.10 a	16.16 a	50.08 a	51.30 a	46.51 a	54.48 a
S_3 (½ at sowing + ½ two months later)	9.61 c	11.23 c	46.03 c	46.14 c	16.20c	20.97 c
F. test	**	**	**	**	**	**
Interaction effect :						
N × P	*	**	NS	**	*	NS
N × S	**	**	NS	NS	**	**
S × P	*	*	NS	NS	**	**
Cultivar differences :						
Sakha 93	11.01		47.91		28.87	
Gemmiza 9		12.65		48.41		34.56
T. test	*		NS		NS	

Table (4-a): Total phosphorus uptake and translocation and recovery efficiency as affected by N × P interaction, as well as, response equations (combined).

N level kgN/fad	P levels (kg P_2O_5/fad)				Response equation	Y_{max}	X_{max} (kg P_2O_5/fad)
	0	20	40	60	= a + bx – cx^2		
				Total P uptake			
				Sakha 93			
	D	C	B	A			
50	5.89 b	8.65 b	10.00 b	11.56 b	5.976 + 2.736x	-	-
	D	C	B	A			
100	7.72 a	11.34 a	12.96 a	14.37 a	7.810 + 3.816x – 0.553 x^2	14.39	69.0
				Gemmiza 9			
	D	C	B	A			
50	6.72 b	10.35 b	11.74 b	13.38 b	6.847 + 3.631x – 0.498 x^2	13.47	72.9
	D	C	B	A			
100	8.61 a	12.71 a	14.86 a	16.18 a	8.666 + 4.571x – 0.695 x^2	16.18	65.8
				P translocation efficiency			
				Gemmiza 9			
	B	B	A	A			
50	43.41 a	44.32 b	47.66 b	48.77 b	43.08 + 2.092x	-	-
	B	A	A	A			
100	44.56 a	50.67 a	50.62 a	51.40 a	44.89 + 6.057x – 1.333 x^2	51.77	45.4
				Phosphorus apparent recovery			
				Sakha 93			
		A	B	B			
50	-	31.51 b	23.46 b	21.58 b	31.51 – 11.14x – 3.085 x^2	-	-
		A	B	C			
100	-	41.39 a	29.97 a	25.31 a	41.39 – 14.80x – 3.380 x^2	-	-

- Not predicted

Table (4-b): Total phosphorus uptake and phosphorus apparent recovery of the two wheat cultivars as affected by N × S interaction (combined).

N level kg/fad	Splitting of phosphorus		
	S_1	S_2	S_3
	Total P uptake		
	Sakha 93		
	B	**A**	**C**
50	**9.38 b**	**12.35 b**	**8.47 b**
	B	**A**	**C**
100	**12.07 a**	**15.85 a**	**10.75 a**
	Gemmiza 9		
	B	**A**	**C**
50	**10.90 b**	**14.49 b**	**10.08 b**
	B	**A**	**C**
100	**13.55 a**	**17.83 a**	**12.37 a**
	Phosphorus apparent recovery		
	Sakha 93		
	B	**A**	**C**
50	**20.82 b**	**40.96 b**	**14.77 a**
	B	**A**	**C**
100	**26.96 a**	**52.07 a**	**17.64 a**
	Gemmiza 9		
	B	**A**	**C**
50	**25.81 a**	**49.88 b**	**20.08 a**
	B	**A**	**C**
100	**30.67 a**	**59.09 a**	**21.86 a**

Table (4-c): Total phosphorus uptake and phosphorus apparent recovery of the two wheat cultivars as affected by S × P interaction, as well as, response equations (combined).

N level kgN/fad	P levels (kg P_2O_5/fad)			Response equation	Y_{max}	X_{max}
	20	40	60	= a + bx – cx^2		
			Total P uptake			
			Sakha 93			
	C	B	A			
S_1	9.38 b	10.64 b	12.16 b	9.25 + 1.520 x	-	-
	C	B	A			
S_2	12.30 a	14.24 a	15.75 a	12.30 + 1.725x	-	-
	C	B	A			
S_3	8.30 c	9.55 c	10.98 c	8.24 + 1.520x	-	-
			Gemmiza 9			
	C	B	A			
S_1	10.82 b	12.10 b	13.76 b	10.70 + 1.850x	-	-
	C	B	A			
S_2	14.16 a	16.36 a	17.95 a	14.20 + 2.188x	-	-
	C	B	A			
S_3	9.62 c	11.44 c	12.62 c	9.62 + 2.140x	-	-
			Phosphorus apparent recovery			
			Sakha 93			
	A	B	B			
S_1	29.39 b	21.91 b	20.38 b	29.39 – 10.46x + $2.975x^2$	-	-
	A	B	C			
S_2	62.91 a	42.55 a	34.08 a	62.91 – 26.32x + 5.945 x^2	-	-
	A	A	A			
S_3	17.04 c	15.68 c	15.88 c	17.04 – 2.140x + 0.780 x^2	-	-
			Gemmiza 9			
	A	B	B			
S_1	36.06 b	25.41 b	23.25 b	36.07 – 14.91x + 4.245 x^2	-	-
	A	B	C			
S_2	74.36 a	49.83 a	39.26 a	74.36 – 31.51x + 6.980 x^2	-	-
	A	A	A			
S_3	22.38 c	21.61 b	18.92 b	23.02 – 3.650x – 0.960 x^2	-	-

- Not predicted

Table (5): Phosphorus physiological efficiency, P agrophysiological efficiency, P utilization efficiency and P agronomic efficiency of the two wheat cultivars as affected by N levels and splitting of different levels of phosphorus in combined analysis.

Main effects and interactions	Phosphorus physiological efficiency (kg/kg P) (PPE)		Phosphorus agrophysiological efficiency (kg/kg P) (PAPE)		Phosphorus utilization efficiency (kg/kg P) (PUE)		Phosphorus agronomic efficiency (kg/kg P) (PAE)	
	Combined		Combined		Combined		Combined	
	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9	Sakha 93	Gemmiza 9
Nitrogen levels effect : (N)								
50 kg N/fd	146.4	165.4	105.8	104.4	33.29	47.49	23.82	30.09
100 kg N/fad	127.4	131.5	108.3	98.9	35.15	43.25	29.56	31.83
F. test	N.S	*	N.S	N.S	N.S	*	**	N.S
Phosphorus levels effect : (P)								
Check	-	-	-	-	-	-	-	-
20 kg P_2O_5/fad	162.9 a	171.0 a	128.5 a	121.3 a	47.19 a	62.67 a	36.64 a	43.50 a
40 kg P_2O_5/fad	133.0 b	147.7 b	104.1 b	98.6 b	30.97 b	42.12 b	24.39 b	28.22 b
60 kg P_2O_5/fad	114.5 c	126.7 c	88.5 c	85.0 c	24.50 c	31.33 c	19.02 c	21.15 c
F. test	**	**	**	**	**	**	**	**
Maximum response	55.59	Linear	47.10	40.80	22.80	33.13	11.26	14.22
Maximum X	82.5		85.5	79.9	63.3	72.1	55.6	57.2
Phosphorus splitting effect : (S)								
S_1 (at sowing)	148.5 b	168.0 a	115.6 b	111.7 b	34.68 b	46.41 b	27.25 b	31.15 b
S_2 (½ at sowing + ½ one month later)	90.3 c	101.2 b	68.7 c	67.5 c	41.51 a	54.30 a	31.65 a	36.69 a
S_3 (½ at sowing + ½ two months later)	171.5 a	176.2 a	136.8 a	125.8 a	26.47 c	35.42 c	21.16 c	25.05 c
F. test	**	**	**	**	**	**	**	**
Interaction effect :								
N × P	N.S	**	**	**	**	**	**	**
N × S	N.S	N.S	N.S	N.S	*	**	N.S	N.S
S × P	N.S	N.S	N.S	N.S	**	**	**	**
Cultivar differences :								
Sakha 93	136.8		107.0		34.22		26.69	
Gemmiza 9		148.5		101.6		45.37		30.96
T. test	N.S		N.S		N.S		N.S	

Table (5-a) : Phosphorus physiological efficiency, agrophysiological, utilization efficiency and agronomic efficiency as affected by N × P interaction, as well as, response equations (combined).

N level kgN/fad	P levels (kg P_2O_5/fad) 0	20	40	60	Response equation = a + bx – cx^2	Y_{max}	X_{max}
			Phosphorus physiological efficiency				
			Gemmiza 9				
		A	A	B			
50	-	176.1 a	170.1 a	150.0 a	180.8 – 27.15x + 7.050x^2	-	-
		A	B	C			
100	-	165.9 a	125.3 b	103.3 b	165.9 – 49.90 + 9.30 x^2	-	-
			Phosphorus agrophysiological				
			Sakha 93				
		A	A	A			
50	-	115.6 a	105.0 a	96.8 a	115.6 – 11.80 x	-	-
		A	B	C			
100	-	141.4 a	103.2 a	80.3 a	141.4 – 45.85 x	-	-
			Gemmiza 9				
		A	A	A			
50	-	109.3 a	107.4 a	96.6 a	112.2 – 15.25x + 4.450 x^2	-	-
		A	B	C			
100	-	133.4 a	89.9 a	73.4 a	133.4 – 57.0x + 13.50 x^2	-	-
			Phosphorus utilization efficiency				
			Sakha 93				
		A	B	C			
50	-	42.48 b	30.92 a	26.47 a	42.49 – 15.13x + 3.56 x^2	-	-
		A	B	C			
100	-	51.90 a	31.02 a	22.52 b	51.90 – 27.07x + 6.19 x^2	-	-
			Gemmiza 9				
		A	B	C			
50	-	63.32 a	44.29 a	34.88 a	63.32 – 23.84x – 4.81 x^2	-	-
		A	B	C			
100	-	62.02 a	39.95 b	27.79 b	62.04 – 27.14x + 5.01 x^2	-	-
			Phosphorus agronomic efficiency				
			Sakha 93				
		A	B	C			
50	-	29.60 b	22.35 b	19.50 a	29.60 – 9.45x + 2.20 x^2	-	-
		A	B	C			
100	-	43.68 a	26.44 a	18.55 a	43.68 – 21.92x – 4.68 x^2	-	-
			Gemmiza 9				
		A	B	C			
50	-	39.47 b	28.13 a	22.66 a	39.48 – 14.28x + 2.94 x^2	-	-
		A	B	C			
100	-	47.54 a	28.32 a	19.65 a	47.55 – 24.51 x – 5.28 x^2	-	-

- Not predicted

Table (5-b): Phosphorus utilization efficiency of the two wheat cultivars as affected by N × S interaction (combined).

N level kgN/fad	Splitting of phosphorus		
	S_1	S_2	S_3
	Phosphorus utilization efficiency		
	Sakha 93		
	B	A	C
50	33.73 b	41.54 a	24.61 b
	B	A	C
100	35.63 a	41.48 a	28.32 a
	Gemmiza 9		
	B	A	C
50	47.94 a	57.51 a	37.03 a
	B	A	C
100	44.87 b	51.09 b	33.80 b

Table (5c): Phosphorus utilization efficiency and phosphorus agronomic efficiency the two wheat cultivar as affected by S × P interaction, as well as, response equations (combined).

N level kgN/fad	P levels (kg P_2O_5/fad)			Response equation $= a + bx - cx^2$	Y_{max}	X_{max}
	20	40	60			
			Phosphorus utilization efficiency			
			Sakha 93			
	A	B	C			
S_1	47.80 b	31.76 b	24.48 b	$47.80 - 20.42x + 4.38\ X^2$	-	-
	A	B	C			
S_2	59.71 a	36.94 a	27.89 a	$59.71 - 29.63x + 6.86\ X^2$	-	-
	A	B	C			
S_3	34.08 c	24.21 c	21.11 c	$34.09 - 13.27x + 3.39\ X^2$	-	-
			Gemmiza 9			
	A	B	C			
S_1	64.60 b	42.42 b	32.19 a	$64.60 - 28.17x + 5.98\ X^2$	-	-
	A	B	C			
S_2	77.98 a	49.17 a	35.75 a	$77.99 - 36.52x + 7.70\ X^2$	-	-
	A	B	C			
S_3	45.42 c	34.78 c	26.06 b	$45.42 - 11.60x$	-	-
			Phosphorus agronomic efficiency			
			Sakha 93			
	A	B	C			
S_1	37.35 b	25.12 b	19.29 b	$37.40 - 15.42x + 3.40\ X^2$	-	-
	A	B	C			
S_2	44.60 a	28.79 a	21.57 a	$44.59 - 20.10x + 4.30\ X^2$	-	-
	A	B	C			
S_3	27.98 c	19.27 c	16.21 c	$27.98 - 11.55x - 2.83\ X^2$	-	-
			Gemmiza 9			
	A	B	C			
S_1	43.66 b	28.28 b	21.51 ab	$43.67 - 19.70x + 4.31\ X^2$	-	-
	A	B	C			
S_2	53.33 a	32.75 a	23.98 a	$53.34 - 26.50x + 5.91\ X^2$	-	-
	A	B	C			
S_3	33.53 c	23.64 c	17.97 b	$33.53 - 12.00x + 2.11\ X^2$	-	-

- Not predicted