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EFFICIENCY OF SOIL AND FOLIAR PHOSPHORUS APPLICATIONS UNDER DIFFERENT NITROGEN LEVELS ON POTATO PRODUCTION

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ABSTRACT: *The present investigation was conducted to study the interactive effect of nitrogen (N) rates of 120 and 180 kg. Fed-1 and soil-foliar combined phosphorus (P) treatments on plant growth, tuber yield and tuber quality of potato, Diamant variety (Solanum tuberosum L.), under relatively high pH soil. Seven P fertilization treatments were investigated. Phosphorus treatments were the combinations of two foliar concentrations, i.e., 500 and 1000 ppm P2O5 and basal dressings of 0, 20 and 40 kg P2O5. Fed-1, in addition to the recommended rate of 60 kg P2O5. Fed-1 soil phosphorus as a check control. All soil phosphorus amendments were applied before planting during soil preparation, whereas foliar treatments were sprayed at complete plant emergence and at two weeks later.*

The higher N application rate (180 kg. Fed-1) accelerated FW of foliage by 11% and plant height by 6% during 1998 as compared to the lower N level. The increase of N application rate from 120 to 180 kg. Fed.-1 enhanced tuber yield by 10-13%, in both years. Soil application of 180 kg N. Fed^{-1} increased percentage of leaf P by 4.5, 13.7 and 4.8% in 1997, and 2.3, 0 and 5% in 1998, at 40, 60 and 80 DAP, respectively. In tubers, dry matter, starch and percentage of P did not respond to the increase of N rate. On the contrary, higher tuber N (2-4%) and potassium (1-3%) were determined as N rate increased to 180 kg. Fed^{-1}.

Soil amendment of 60 kg. P_2O_5. Fed^{-1} resulted in 17-34 and 11-22% higher FW of foliage as compared to the other treatments during 1997 and 1998, respectively. However, DW of foliage showed no response to any of the P application treatments. Rates of soil P less than 40 kg P_2O_5. Fed^{-1} reduced plant height, regardless P_2O_5 concentration of foliar fertilization. Soil application of 60 kg and that of 40 kg P_2O_5. Fed^{-1} combined with 1000 ppm P_2O_5 foliar spray consistently produced the highest tuber yields and increased percentage of tuber P and K in both years. Soil fertilization of 40 kg P_2O_5. Fed^{-1} followed by foliar spray of 1000 ppm P_2O_5 showed the greatest percentage of leaf P at all sampling dates of 40, 60 and 80 DAP. Regardless foliar concentration treatment, soil application of 40 kg P_2O_5. Fed^{-1} gave the highest percentage of tuber potassium. It is recommended, therefore, to apply 180 Kg N. Fed.$^{-1}$ combined with soil dressing of 60 kg P_2O_5. Fed^{-1} or 40 Kg P_2O_5. Fed.$^{-1}$ followed by

1000 ppm P_2O_5 foliar fertilization to produce optimum tuber yield of Diamant variety under relatively high pH soils.

***Key Words:** Egypt, nitrogen, phosphorus, soil amendment, foliar fertilization, potatoes, Diamant variety.*

INTRODUCTION

It is generally accepted that the application of mineral nutrients is required for maximum potato production. Potatoes respond well to optimum fertilizer levels in terms of both yield and quality. In the presence of sufficient potassium and phosphorus, nitrogen markedly increases the size of plant vegetative growth and leaf area (Rajanna et al.,1987; Burton 1989; Harris 1992; Karadoan, 1995). Early optimum nitrogen application also enhanced tuber yield (Rajanna et al., 1987; Sharma and Arora, 1987 and 1990; Karadoan, 1995) which is more likely due to the increase of number of tubers per plant. On the contrary, excessive nitrogen can over stimulate foliage growth, delay tuber initiation, delay maturity and reduced tuber dry matter (Voloshin, 1991). In addition, nitrogen application enhanced both leaf (Smith, 1968) and tuber (Sharma and Arora, 1990; Koszaski et al., 1995) phosphorus uptake.

The need for phosphorus, like nitrogen, is critical during the early stages of plant growth where normal meristem development and rapid plant growth are necessary for high yield (Burton, 1989). Hence, it is rather important to insure adequate phosphorus availability to fulfill plant requirements, in order to accomplish high production of potatoes. The positive effect of phosphorus on tuber yield (EL-Sayed and Hamail,1991; Fontes and Fontes, 1991; Khan, 1991) is probably due to the increase in tuber number (Sparrow et al., 1992), tuber size (Smith, 1968; Berestov, 1986) and/or tuber weight (Sharma and Arora, 1987). The application of phosphorus, however, does not appear to have a marked consistent effect upon DM of the tubers. Burton (1989) reported a fluctuate effect, whereas soil or foliar application of phosphorus was found to increase tuber DM and starch (El-Sayed and Hamail, 1991).

Phosphorus uptake by potato plants is influenced by rate of application and level of soil available phosphorus (Smith, 1968; Gupta and Saxena, 1981). Soil reactions may affect the proportion of various elements absorbed by the plant. In Egypt, phosphate fixation is one of the reactions that occurs in the alkaline high pH soils. That reaction transforms soluble phosphate to unavailable calcium forms. As a result, phosphate absorption is reduced with corresponding negative effects on the development of the plant (see Burton, 1989). One of the possibilities to augment the supply of P under such conditions is through foliar application which possess the advantage of quick action. However, the amount of fertilizer that can be applied through foliar application is limited as compared to the actual plant requirements. This method of application is expected to be effective as phosphorus can be transported from foliage to the other parts of the plant. Moreover, it may insure more precise phosphorus application (Lewis and Kettlewell, 1992) especially under the condition of high pH soil.

The objective of the present study, therefore, was to study the effect of nitrogen and soil-foliar combined phosphorus treatments on nutrient uptake, growth and tuber yield and quality of potato plants.

MATERIALS AND METHODS

The present investigation was conducted during the spring seasons of 1997 and 1998 at El-Zahraa village, Dakahlyla province, using Diamant cv. (*Solanum tuberosum* L.) certified seed tubers on a clay-loam soil. Cultural management, disease and pest control programs were followed according to the recommendations of the Egyptian Ministry of Agriculture. The chemical characteristics of the experimental soil at depth of 0-30 cm are given in Table 1.

Total nitrogen (N) was either 120 or 180 kg. Fed^{-1} applied in the forms of ammonium sulphate (20.6% N) and ammonium nitrate (33.5% N). Two thirds of the total N as ammonium sulphate were equally divided and applied before planting and at complete plant emergence. The rest of N fertilizer was soil dressed in the form of ammonium nitrate at two weeks following complete plant emergence stage.

Table 1. Chemical characteristics of the experimental soil.

Characteristics	pH	EC (dS/m)	OM (%)	N (ppm)	P (ppm)	K (ppm)
Value	7.9	1.6	2.8	65	18	460

Seven phosphorus (P) treatments were investigated. . Phosphorus treatments were the combinations of two foliar concentrations, i.e., 500 and 1000 ppm P_2O_5; each with basal dressings of 0, 20 and 40 kg P_2O_5. Fed^{-1}, in addition to the recommended rate of 60 kg P_2O_5. Fed^{-1} soil application as check control. The single super-phosphate (15% P_2O_5) was used as phosphorus source for all P treatments. Foliar phosphorus treatments were applied at complete plant emergence and at two weeks later. Soil phosphorus application were amended before planting (during soil preparation). The experimental design was a split plot with three replicates. Nitrogen levels resembled the main plots while the seven phosphor treatments represented the sub ones. Cut seed tubers of approximate equal sizes were planted in rows 0.75 m apart and 0.25 m within the row on February 12 and 15 in 1997 and 1998 seasons, respectively. The experimental unit area was 18.75 m2 consisted of 5 rows; each of 5 m length. All units received identical amounts of composted animal manure (20 t. Fed-1) and potassium (96 kg K2O. Fed-1); provided from the sulphate of potash (48% K2O). All manure along with 50% of the total potassium were applied before planting (during soil preparation), whereas the rest of potassium was added at complete plant emergence. For conversion purposes, one Feddan (Fed.) is equivalent to 0.42 ha.

Petioles of the youngest fully expanded twenty mature leaves (the fifth leaf from the top of the plant) of each treatment were randomly collected at 40, 60 and 80 days after planting (DAP) to determine leaf P concentration. Leaf samples were washed with distilled water and dried at 65 oC for 48 h in air-forced ventilated oven.

At 75 DAP, fresh weight (FW) and dry matter (DM) percentage of foliage (leaves and stems) were determined using ten plants per each experimental unit. To calculate the percentage of dry matter, foliage was oven-dried at 105 oC to constant weight in air-forced ventilated oven. Plant height (cm) was measured using ten plants at 90 DAP.

At harvest, total yield of the middle 3 rows (11.25 m2) per each experimental unit was recorded. Percentage of tuber starch (A.O.A.C, 1975) were determined using medium-sized tubers (35-55 mm). Dry matter percentage was determined by grating 5 halves of tubers per each treatment, weighed and oven dried at 105 oC to constant weight and DM percentage was then calculated. For NPK analyses, 10 tubers of the medium size were washed with distilled water and peeled to separate tuber peel from the medulla tissue (flesh). Medulla tissues were then oven-dried at 65oC for 48 h in air-forced ventilated oven. Percentage of nitrogen (Koch and McMeckin, 1924), phosphorus (Troug and Meyer, 1939) and potassium (Brown and Lilliland, 1946) were analyzed in DM of leaves and medulla tissues, in both years.

Data were statistically analyzed using a General Linear Model procedure of SAS Institute (1989). The Fishers protected least significant difference (LSD) at $P \leq 0.05$ was employed to separate the treatment means.

RESULTS AND DISCUSSION

Fresh weight and dry matter of foliage. The increase of N rate from 120 to 180 Kg. Fed.-1 accelerated fresh weight of foliage by 4 and 11% in 1997 and 1998, respectively, (Table 2). However, results were only significant ($P \leq 0.05$) in 1998. The positive response of foliage FW to the higher N level might be attributed to the adequate N uptake and the subsequent enhancement of meristematic cell division and expansion (Burton 1989; Harris 1992) resulted in marked increases of leaf area and stem growth.

In both years, the ground fertilization of 60 Kg P2O5. Fed.-1 significantly increased FW of foliage as compared to the rest of phosphorus treatments, regardless of N rate. In 1997, soil application of 60 Kg P2O5. Fed.-1 resulted in 23.5, 34 and 22% higher FW of foliage than that of 0, 20 and 40 kg P2O5. Fed.-1 followed by foliar spray of 500 ppm of P2O5, respectively, (Table 2). The corresponding increases as compared to the same levels of soil dressings with foliar application of 1000 ppm were 22, 28 and 17%, respectively. In 1998 study, soil amended with 60 kg P2O5. Fed.-1 increased foliage FW by 22, 11 and 18% as compared to that of 0, 20 and 40 kg P2O5. Fed.-1 followed by foliar spray of 500 ppm of P2O5, respectively. The corresponding increments of FW of foliage, when foliar concentration of 1000 ppm P_2O_5 was sprayed, were 18, 18 and 11%, respectively, (Table 2).

Results indicated the superiority of using 60 Kg P_2O_5. Fed.$^{-1}$ soil amendment in increasing FW of foliage over soil-foliar combination treatments. Moreover, neither the 500 nor the 1000 ppm P_2O_5 foliar applications compensated the reduction of foliage FW resulted from basal phosphorus applications lower than 60 Kg P_2O_5. Fed.$^{-1}$. This might indicate a positive and encouraging effect of the 60 Kg P_2O_5. Fed.$^{-1}$ phosphorus level, than foliar treatments, on root development. This would optimize nutrient uptake and increase meristematic activity and leaf expansion (Burton, 1989) resulting in greater vegetative growth.

Table 2. Effect of nitrogen (N) and phosphorus (P_2O_5) application treatments on fresh weight of foliage (g. plant^{-1}) at 75 days after planting during 1997 and 1998 spring studies.

N rate (Kg. Fed.$^{-1}$)	Phosphorus treatments[1]							Mean
	500 ppm + 0 Kg	500 ppm + 20 Kg	500 ppm + 40 Kg	1000 ppm + 0 Kg	1000 ppm + 20 Kg	1000 ppm + 40 Kg	0 ppm + 60 Kg	
				1997				
120	232.3	209.0	226.7	230.0	227.0	217.0	276.0	231.1
180	226.7	214.3	237.7	233.3	215.7	264.7	291.0	240.5
Mean	229.5	211.7	232.2	231.7	221.4	240.9	283.5	
				1998				
120	228.7	202.3	218.3	230.7	217.3	225.7	264.0	226.7
180	216.3	285.7	242.7	231.0	241.3	261.7	279.0	251.1
Mean	222.5	244.0	230.5	230.9	229.3	243.7	271.5	

LSD $_{\leq 0.05}$:	N rate	P_2O_5 treatment	N x P_2O_5
1997	NS	18.0	20.8
1998	7.3	16.4	NS

[1][500 and 1000 are foliar ppm of P_2O_5, whereas 0, 20, 40 and 60 are kg soil amendments of P_2O_5. Fed^{-1}]

The interactive effect of nitrogen and phosphorus treatments on FW of foliage was significant during 1997 (Table 2). Results indicated that the highest foliage FW were obtained as 60 kg P_2O_5 was combined with 120 kg N. Fed^{-1} or when soil application of 180 kg N. Fed^{-1} and that of 40 kg P_2O_5 followed by 1000 ppm P_2O_5 foliar spray were used.

None of the studied factors, as well as their interaction, exerted any significant effect on percentage of foliage DM (Table 3). It is obvious that all foliar associated soil phosphorus levels had similar significant effects on percentage of foliage DM. However, soil application of 40 kg P_2O_5. Fed^{-1} followed by 1000 ppm foliar fertilization of P_2O_5 tended to increase DM of foliage when combined with 180 kg N. Fed^{-1}, in both years. This could be due to the positive effect of foliar P application on shoot dry weight of potato plants (Fontes and Fontes, 1991).

Plant height. Increasing N application rate from 120 to 180 Kg. Fed^{-1}. significantly ($P \leq 0.05$) increased plant height by 6% during 1998 study (Table 4). Similar results for the positive effect of high N level on plant height were previously reported (Rajanna et al., 1987; Karadoan, 1995).

Irrespective of N level, phosphorus application treatments significantly affected plant height during 1997 (Table 4). Results showed comparable effects of 60 and 40 kg P_2O_5. $Fed.^{-1}$ soil applications, regardless of foliar concentrations, on plant height (Table 4).

Basal fertilization of 60 kg P_2O_5. $Fed.^{-1}$ significantly ($P \leq 0.05$) increased plant height by 8 and 6% as compared to foliar treatments of 500 and 1000 ppm of P_2O_5 with no soil phosphorus, respectively. The respective improvements in plant height as compared to soil-foliar treatments of 20 kg P_2O_5. $Fed.^{-1}$ were 10 and 6%, respectively. The comparable effect of 40 to that of 60 kg P_2O_5. $Fed.^{-1}$ soil application on plant height might indicate that P requirements for optimum plant height is in the range of 40-60 kg P_2O_5. Fed^{-1}. Soil application of lower level than 40 kg P_2O_5 might result in negative effect on plant height, as indicated above. On the contrary, Khan (1991) reported no relationship between plant height and the increase of soil phosphorus level.

Table 3. Effect of nitrogen (N) and phosphorus (P_2O_5) application treatments on percentage of foliage dry matter at 75 days after planting during 1997 and 1998 spring studies.

N rate (Kg. Fed.$^{-1}$)	Phosphorus treatments[1]							Mean
	500 ppm + 0 Kg	500 ppm + 20 Kg	500 ppm + 40 Kg	1000 ppm + 0 Kg	1000 ppm + 20 Kg	1000 ppm + 40 Kg	0 ppm + 60 Kg	
				1997				
120	12.99	12.66	12.92	12.74	12.82	12.89	12.96	12.85
180	12.74	12.71	12.85	12.92	12.80	13.49	13.04	12.93
Mean	12.86	12.69	12.89	12.83	12.81	13.19	13.00	
				1998				
120	12.84	12.58	12.70	12.79	12.73	12.93	12.98	12.79
180	12.63	12.80	12.78	12.82	12.92	13.00	12.88	12.83
Mean	12.74	12.69	12.74	12.81	12.83	12.96	12.93	

LSD $_{\leq 0.05}$:	N rate	P_2O_5 treatment	N x P_2O_5
1997	NS	NS	NS
1998	NS	NS	NS

[1][500 and 1000 are foliar ppm of P_2O_5, whereas 0, 20, 40 and 60 are kg soil amendments of P_2O_5. Fed^{-1}]

The interaction effect of nitrogen and phosphorus treatments on plant height was significant ($P \leq 0.05$) during 1997 (Table 4). Plants of 60 kg P_2O_5. Fed.$^{-1}$, irrespective of N level, and those of 180 kg N ground fertilized with 40 kg P_2O_5. Fed.$^{-1}$, regardless of foliar concentration, showed comparable and greatest plant height values. In combination with 120 kg N. Fed.$^{-1}$, plants fertilized with 60 kg P_2O_5. Fed.$^{-1}$ showed 7, 9 and 4% more plant height than those ground amended with 0, 20 and 40 kg P_2O_5. Fed.$^{-1}$ and foliar sprayed with 500 ppm of P_2O_5, respectively. The corresponding increases in plant height than those foliar sprayed with 1000 ppm P_2O_5 were 6, 5 and 5%, respectively. The same trend was observed among phosphorus application treatments when soil was supplied with 180 kg N. Fed.$^{-1}$ (Table 4). Similar results for the general positive effect of soil phosphorus application on plant height were reported by Sharara et al. (1985).

Total yield. Tuber yield (t. Fed-1) was significantly enhanced as rate of applied N increased from 120 to 180 Kg. fed.-1, regardless phosphorus treatments (Table 5). Yield increase reached about 13 and 10 % for 1997 and 1998, respectively. The positive influence of the higher N rate on tuber yield might be due to the enhancing effect of adequate N on cell division and elongation (Rajanna et al., 1987; Sharma and Arora, 1987 and 1990; Karadoan, 1995) resulting in larger leaf area and plant growth (Burton, 1989; Harris, 1992). Consequently, higher efficiency of photosynthetic assimilation and assimilate translocation resulted in production of greater tuber yield of higher N treatments.

Table 4. Effect of nitrogen (N) and phosphorus (P_2O_5) application treatments on plant height (cm) at 90 days after planting during 1997 and 1998 spring studies.

N rate (Kg. Fed.$^{-1}$)	Phosphorus treatments[1]							Mean
	500 ppm + 0 Kg	500 ppm + 20 Kg	500 ppm + 40 Kg	1000 ppm + 0 Kg	1000 ppm + 20 Kg	1000 ppm + 40 Kg	0 ppm + 60 Kg	
				1997				
120	39.0	38.3	40.0	39.3	39.6	39.6	41.6	39.6
180	38.3	38.0	41.3	39.3	39.0	41.6	42.0	39.9
Mean	38.6	38.1	40.7	39.3	39.3	40.6	41.8	
				1998				
120	38.6	37.6	38.0	39.3	38.3	38.0	38.6	38.3
180	38.6	40.6	41.3	40.0	41.0	41.3	41.0	40.5
Mean	38.6	39.1	39.7	39.7	39.7	39.7	39.8	

LSD $_{\leq 0.05}$:	N rate	P_2O_5 treatment	N x P_2O_5
1997	NS	1.3	0.3
1998	0.9	NS	NS

[1][500 and 1000 are foliar ppm of P_2O_5, whereas 0, 20, 40 and 60 are kg soil amendments of P_2O_5. Fed^{-1}]

In 1997, soil application of 40 kg P_2O_5. Fed.$^{-1}$ followed by foliar spray of 1000 ppm P_2O_5 gave the highest tuber yield (11.2 t. Fed^{-1}). However, the effect was comparable to that of 40 kg P_2O_5. Fed^{-1} followed by 500 ppm P_2O_5 foliar application and that of 60 kg P_2O_5. Fed.$^{-1}$ (Table 5). Tuber yield was also enhanced as soil phosphorus application increased from 0 to 20 and 40 kg P_2O_5. Fed.$^{-1}$, regardless foliar P treatments. When 1000 ppm P_2O_5 was sprayed in 1997, soil application of 40 kg P_2O_5. Fed.$^{-1}$ increased tuber yield by 16 and 17% as compared to 0 and 20 kg P_2O_5. Fed.$^{-1}$, respectively. The respective increases of tuber yield when 500 ppm P_2O_5 was applied were 12 and 4%, respectively, (Table 5). Soil amendment of 60 kg P_2O_5. Fed.$^{-1}$ resulted in 16 and 8 % higher tuber yield than those of 0 and 20 kg P_2O_5. Fed.$^{-1}$ with foliar application of 500 ppm P_2O_5, respectively.

In 1998, basal fertilization of 40 kg P_2O_5. Fed.$^{-1}$ with 1000 ppm P_2O_5 foliar spray and that of 60 kg P_2O_5. Fed.$^{-1}$ resulted in a similar total yield of 10.3 t. Fed.$^{-1}$ (Table 5). Both treatments gave 17, 26 and 11% higher tuber yield than those of 0, 20 and 40 kg P_2O_5. Fed.$^{-1}$ combined with 500 ppm P_2O_5 foliar spray, respectively. The corresponding increases of tuber yield as compared to soil applications of 0 and 20 kg P_2O_5. Fed.$^{-1}$ with foliar spray of 1000 ppm P_2O_5 were 16 and 23%, respectively.

Irrespective foliar P concaentration, soil amendment of 0 and 20 kg P_2O_5. Fed^{-1} resulted in comparable tuber yield. This could be due to the effectiveness of the accompanied foliar P application as a precise method of fertilization (Lewis and Kettlewell, 1992) in compensating plant needs of phosphorus resulted from the reduction of 20 kg P_2O_5. Fed^{-1} soil phosphorus supply. However, very high foliar concentrations to compensate the reduction of higher amounts than 20 kg P_2O_5. Fed^{-1} of soil phosphorus supply could be harmful. This would be explained based on the detrimental effect of high foliar concentration due to the sensitivity of leaves to high osmotic salts. The positive effect of the 60 kg P_2O_5. Fed.$^{-1}$ application treatment on tuber yield might be explained based on the increase of soil P_2O_5 concentration and its effective role in root development and carbohydrate synthesis resulting in high tuber yield (EL-Sayed and Hamail,1991; Fontes and Fontes, 1991; Khan, 1991). That increase in tuber yield could be attributed to the increase of tuber size (Smith, 1968; Berestov, 1986), tuber weight (Sharma and Arora, 1987) and/or number of tubers per plant (Sparrow et al., 1992). On the contrary, our results did not agree with those of Rajanna et al. (1987) where soil phosphorus application resulted in inconsistent tuber yield.

The interaction effect of nitrogen and phosphorus treatments on tuber yield was significant during 1997 study (Table 5). In this regard, soil application of 180 Kg N. Fed.$^{-1}$ combined with 60 or that of 40 Kg P_2O_5. Fed.$^{-1}$ followed by 1000 ppm foliar spray gave the highest potato tuber yield (Table 5).

Dry matter and starch of tubers. Increasing N rate from 120 to 180 Kg. Fed.$^{-1}$ had no significant effect on percentage of tuber DM (Table 6) and starch (Table 7). In support to that, high N application rates slightly increased tuber DM with no significant differences among N application rates (Koszaski et al., 1995). On the contrary, high N application rates ranged from 120-150 kg. ha^{-1} were reported to decrease tuber DM content as compared to 60 and 90 kg N. ha^{-1} (Voloshin, 1991).

Table 5. Effect of nitrogen (N) and phosphorus (P_2O_5) application treatments on total tuber yield (t. Fed^{-1}) at harvest during 1997 and 1998 spring studies.

N rate (Kg. Fed.$^{-1}$)	Phosphorus treatments[1]							Mean
	500 ppm + 0 Kg	500 ppm + 20 Kg	500 ppm + 40 Kg	1000 ppm + 0 Kg	1000 ppm + 20 Kg	1000 ppm + 40 Kg	0 ppm + 60 Kg	
				1997				
120	9.1	9.1	9.5	9.4	9.4	10.4	9.6	9.5
180	9.4	10.8	11.2	10.0	9.7	12.0	11.9	10.7
Mean	9.3	10.0	10.4	9.7	9.6	11.2	10.8	
				1998				
120	8.3	7.9	8.9	8.4	7.9	9.7	9.8	8.7
180	9.3	8.4	9.6	9.3	8.8	10.8	10.7	9.6
Mean	8.8	8.2	9.3	8.9	8.4	10.3	10.3	

LSD $_{\leq 0.05}$:	N rate	P_2O_5 treatment	N x P_2O_5
1997	0.4	1.0	0.7
1998	0.5	0.6	NS

[1][500 and 1000 are foliar ppm of P_2O_5, whereas 0, 20, 40 and 60 are kg soil amendments of P_2O_5. Fed^{-1}]

Regardless of N rate, differences among phosphorus fertilization treatments were only significant ($P \leq 0.05$) during 1997 (Tables 6 and 7). Plants of 60 Kg P_2O_5. Fed.$^{-1}$, those of 0, 20 and 40 Kg P_2O_5. Fed.$^{-1}$ with foliar spray of 1000 ppm P_2O_5 and those of 0 and 40 Kg P_2O_5. Fed.$^{-1}$ with foliar spray of 500 ppm P_2O_5 showed the highest significant values of tuber DM% (Table 6). However, results indicated different trend for percentage of tuber starch. In this respect, basal amendments of 60 Kg P_2O_5. Fed.$^{-1}$, that of 40 Kg P_2O_5. Fed.$^{-1}$ with foliar spray of 500 ppm P_2O_5 and those of 20 and 40 kg P_2O_5. Fed.[-1] with foliar application of 1000 ppm P_2O_5 resulted on the highest percentage of tuber starch (Table 7). The comparable effects of foliar treatments associated basal rates with the 60 Kg P_2O_5. Fed.[-1] soil application on tuber DM and starch could be due to their accompanied foliar treatment as an effective and precise method of nutrient application (Lewis and Kettlewell, 1992). Regardless of foliar concentration, the high tuber DM and starch as soil phosphorus increased to 40 kg P_2O_5. Fed[-1] might be attributed to the favorable effect of increasing soil phosphorus levels on the enhancement of these quality parameters (EL-Sayed and Hamaii, 1991).

The interaction between phosphorus treatments and nitrogen application levels on tuber DM and starch was not significant in both years (Tables 6 and 7, respectively) indicating that phosphorus exerted its significant effect on tuber DM and starch during 1997 irrespective of N level.

Table 6. Effect of nitrogen (N) and phosphorus (P_2O_5) application treatments on percentage of tuber dry matter during 1997 and 1998 spring studies.

N rate (Kg. Fed.[-1])	Phosphorus treatments[1]							Mean
	500 ppm + 0 Kg	500 ppm + 20 Kg	500 ppm + 40 Kg	1000 ppm + 0 Kg	1000 ppm + 20 Kg	1000 ppm + 40 Kg	0 ppm + 60 Kg	
				1997				
120	21.58	21.28	21.90	21.34	21.78	21.98	21.86	21.67
180	21.91	21.30	21.80	21.82	21.39	21.99	21.91	21.73
Mean	21.75	21.29	21.85	21.58	21.59	21.99	21.89	
				1998				
120	21.91	21.30	21.80	21.82	21.39	21.99	21.91	21.73
180	21.66	21.59	21.58	21.87	21.87	22.04	22.17	21.83
Mean	21.79	21.45	21.69	21.85	21.63	22.02	22.04	

LSD $_{\leq 0.05}$:	N rate	P_2O_5 treatment	N x P_2O_5
1997	NS	0.51	NS
1998	NS	NS	NS

[1][500 and 1000 are foliar ppm of P_2O_5, whereas 0, 20, 40 and 60 are kg soil amendments of P_2O_5. Fed[-1]]

Table 7. Effect of nitrogen (N) and phosphorus (P_2O_5) application treatments on percentage of tuber starch during 1997 and 1998 spring studies.

N rate (Kg. Fed.$^{-1}$)	Phosphorus treatments[1]							Mean
	500 ppm + 0 Kg	500 ppm + 20 Kg	500 ppm + 40 Kg	1000 ppm + 0 Kg	1000 ppm + 20 Kg	1000 ppm + 40 Kg	0 ppm + 60 Kg	
				1997				
120	15.38	15.20	15.64	15.26	15.54	15.69	15.60	15.47
180	15.29	15.52	15.98	15.31	15.58	16.57	16.29	15.79
Mean	15.34	15.36	15.81	15.29	15.56	16.13	15.95	
				1998				
120	15.64	15.18	15.61	15.61	15.31	15.80	15.78	15.56
180	15.58	15.44	15.44	15.66	15.56	16.03	16.12	15.69
Mean	15.61	15.31	15.53	15.64	15.44	15.92	15.95	

LSD $_{\leq 0.05}$:	N rate	P_2O_5 treatment	N x P_2O_5
1997	NS	0.34	NS
1998	NS	NS	NS

[1][500 and 1000 are foliar ppm of P_2O_5, whereas 0, 20, 40 and 60 are kg soil amendments of P_2O_5. Fed^{-1}]

Leaf phosphorus concentration.

Percentage of leaf phosphorus at 40 DAP was, in general, double that obtained at 60 and 80 DAP (Fig. 1A, 1B, 2A and 2B), in both years.

Effect of N application rate: In 1997 (Fig. 1 A), soil application of 180 kg N. Fed^{-1} increased percentage of leaf P at 40, 60 and 80 DAP by 4.5, 13.7 and 4.8% as compared to that of 120 kg N. Fed^{-1}, respectively. The corresponding enhancements of leaf P in 1998 were 2.3, 0 and 5% at 40, 60 and 80 DAP, respectively, (Fig. 1 B).

Effect of phosphorus treatments: The application of 40 kg P_2O_5. Fed^{-1} with foliar spray of 1000 ppm P_2O_5 showed the highest leaf P at all sampling dates.

At 40 DAP, basal application of 40 kg P_2O_5 followed by foliar 1000 ppm P_2O_5 consistently resulted in the highest percentage of leaf P during 1997 (0.48%; Fig. 2 A)

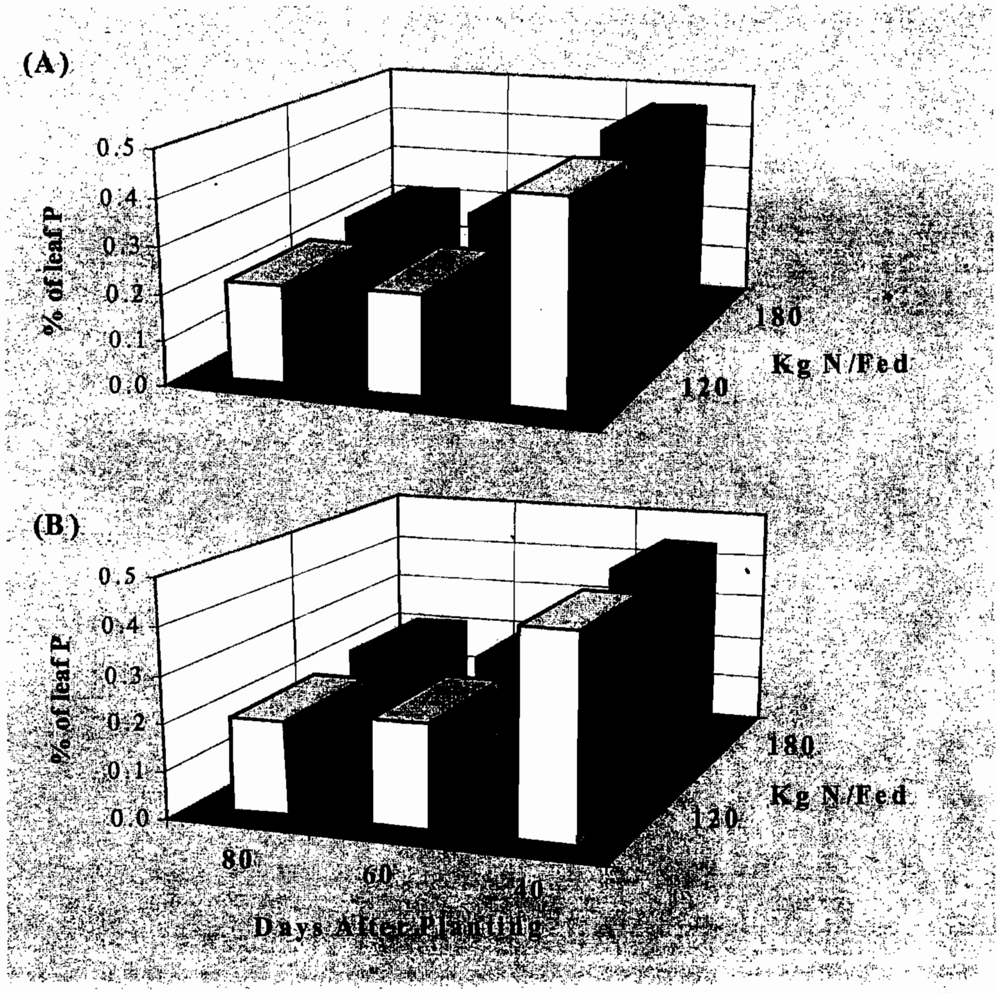

Figure 1. Effect of nitrogen application rate on percentage of leaf phosphorus (P) at 40, 60 and 80 days after planting during 1997 (A) and 1998 (B) spring studies.

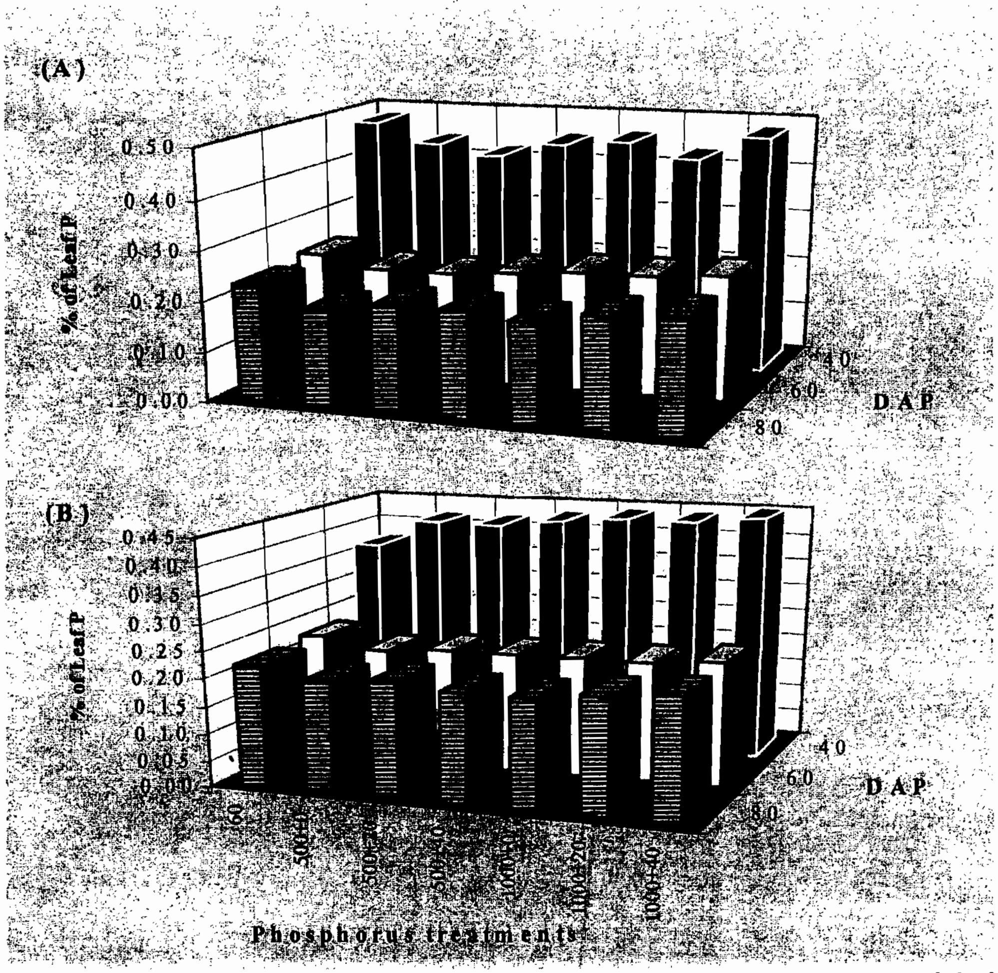

Figure 2. Effect of foliar-soil combined phosphorus treatments on percentage of leaf phosphorus (P) at 40, 60 and 80 days after planting during 1997 (A) and 1998 (B) spring studies. [500 and 1000 are foliar ppm of P_2O_5, whereas 0, 20, 40 and 60 are kg soil amendments of P_2O_5. Fed^{-1}]

and 1998 (0.45%; Fig. 2 B). On the contrary, Soil amendment of 60 kg P_2O_5. Fed^{-1} resulted in inconsistent percentage of leaf phosphorus reached 0.48% in 1997 (Fig. 2 A) dropped to 0.37% in 1998 (Fig. 2 B). In general, soil-foliar phosphorus treatments showed consistent higher leaf P than that of 60 kg P_2O_5. Fed^{-1}.

At 60 and 80 DAP, soil fertilization of 60 kg P_2O_5 and that of 40 kg P_2O_5 with foliar application of 1000 ppm gave consistent higher leaf P than rest of the treatments, in both years (Fig. 2 A and B). In 1997, foliar application of 1000 ppm P_2O_5 tended to increase percentage of leaf P as compared to that of 500 ppm. This could be attributed to the foliar fertilization as a precise method of nutrient application in comparison to soil amendment (Lewis and Kettlewell, 1992), resulting in higher leaf tissue P concentration following application of 1000 ppm P_2O_5 than that of 500 ppm.

Tuber NPK concentrations

Effect of nitrogen rate: As indicated in Figure (3 A), the increase of N application rate from 120 to 180 kg. Fed^{-1} increased tuber N concentration by 4 and 2% during 1997 and 1998, respectively. However, results were only significant in 1997 study. Similar trends were reported where high N rates in the range of 120-150 kg N. ha^{-1} increased tuber total N (Koszaski et al., 1995) and nitrate content (Voloshin, 1991) as compared to lower N levels.

The increase of nitrogen application rate showed no marked effect on percentage of tuber phosphorus (Fig. 3 B), in both years. Previous work, on the contrary, indicated that tuber P uptake was enhanced as N application rate increased from 0 to 250 kg. ha^{-1} with 50 kg N increments (Sharma and Arora, 1990) or as N levels from 75 to 150 kg N. ha^{-1} with 25 kg N increments (Koszaski et al., 1995) were used.

Tuber potassium was also enhanced by 3 and 1% in 1997 and 1998 studies, respectively, as N application rate was elevated from 120 to 180 kg N. Fed^{-1} (Fig. 3 C). However, differences were only significant ($P \leq 0.05$) in 1998. Similar trends for the increase of tuber K as N application rate increased were previously reported (Gupta and Saxena, 1981; Sharma and Arora, 1990; Koszaski et al., 1995).

Effect of phosphorus treatments: Soil application of 60 kg P_2O_5. Fed^{-1} showed the highest tuber N concentration of 1.95 and 1.93% in 1997 and 1998, respectively, (Fig. 4 A). Among basal amendments of each foliar treatment, the application of 40 kg P_2O_5 increased percentage of tuber N than 0 and 20 kg P_2O_5. Fed^{-1} applications.

Soil fertilization of 60 kg P_2O_5. Fed^{-1} and that of 40 kg P_2O_5. Fed^{-1} with 1000 ppm P_2O_5 foliar application significantly increased percentage of tuber P than rest of the treatments (Fig. 4 B) during 1997. Regardless of foliar treatment, soil application of 40 kg P_2O_5. Fed^{-1} significantly increased percentage of tuber P than that of 0 and 20 kg P_2O_5. Fed^{-1}. Similar improvements of tuber P concentration with increased levels of soil phosphorus were reported by Smith (1968).

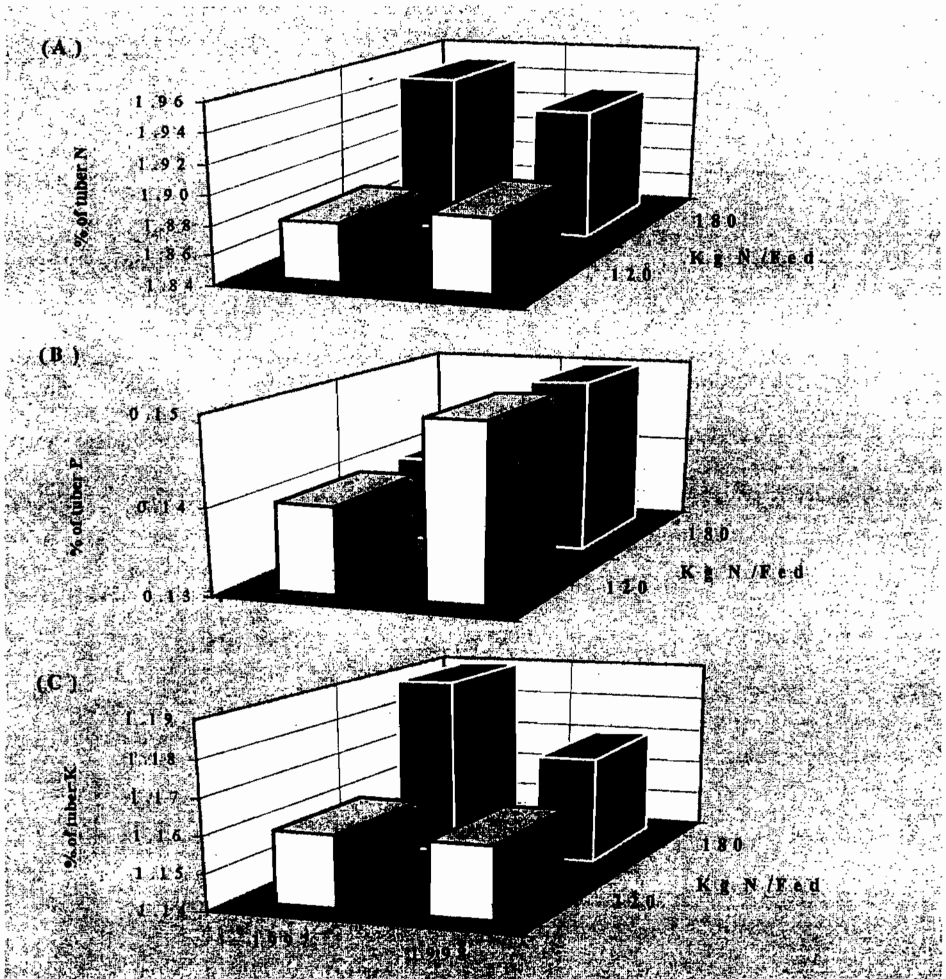

Figure 3. Effect of nitrogen application rate on percentage of tuber nitrogen (A), phosphorus (B) and potassium (C) at harvest during 1997 and 1998 spring studies.

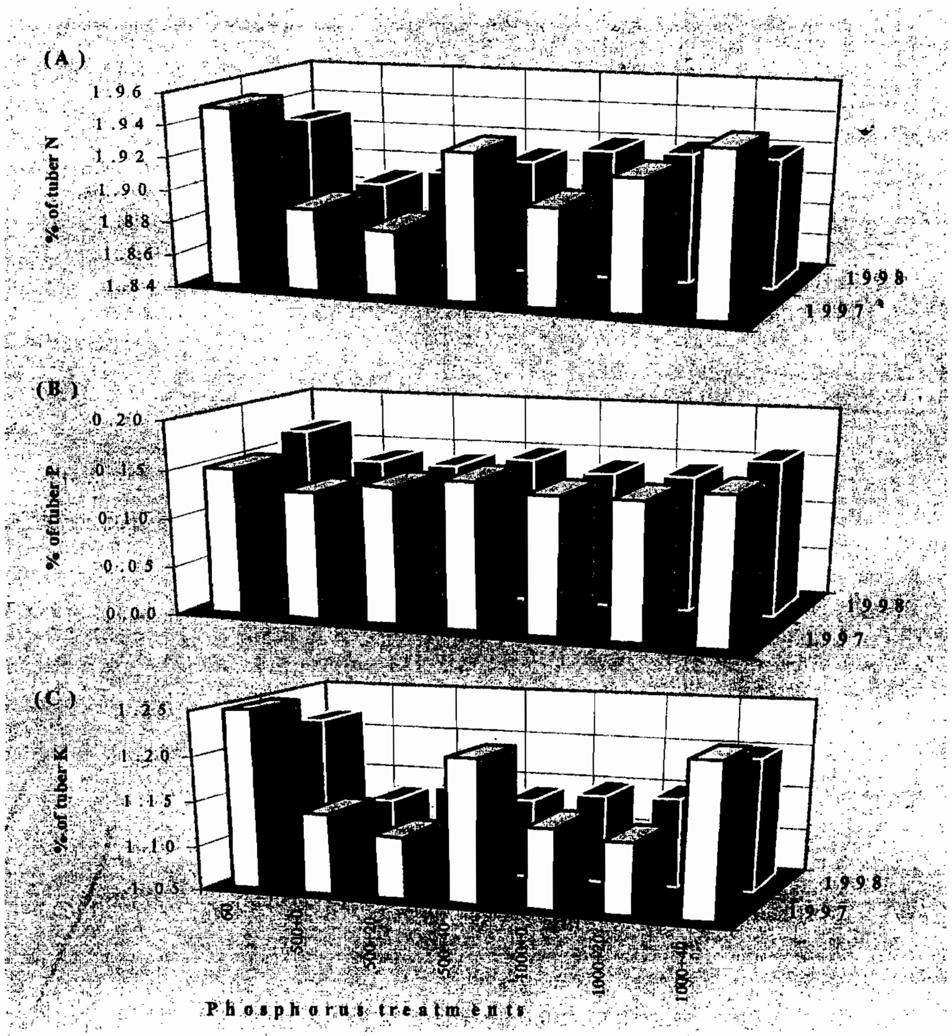

Figure 4. Effect of foliar-soil combined phosphorus application rates on percentage of tuber nitrogen (A), phosphorus (B) and potassium (C) at harvest during 1997 and 1998 spring studies.
[500 and 1000 are foliar ppm of P_2O_5, whereas 0, 20, 40 and 60 are kg soil amendments of P_2O_5. Fed^{-1}]

The application of 60 kg P_2O_5. Fed^{-1} or that of 40 kg P_2O_5. Fed^{-1} followed by foliar 1000 ppm P_2O_5 resulted in the highest comparable tuber K concentration (Fig. 4 C), in both years. Again, soil amendment of 40 kg P_2O_5. Fed^{-1}, irrespective of foliar concentration, increased percentage of tuber K than that of 0 and 20 kg P_2O_5. Fed^{-1}. Similar results for the improvement of tuber K uptake with the increase of soil P application was reported by Gupta and Saxena, 1981.

The present study showed that soil application of 180 Kg N. $Fed.^{-1}$ combined with that of 60 Kg P_2O_5. $Fed.^{-1}$ or that of 40 Kg P_2O_5. $Fed.^{-1}$ followed by foliar application of 1000 ppm P2O5 gave the highest comparable tuber yield of Diamant variety. In addition, the application of 1000 ppm P2O5 foliar treatment could compensate plant needs of P resulted from a 20 kg P2O5. Fed-1 reduction of soil phosphorus supply and improved plant growth and tuber yield. However, when the reduction of soil phosphorus supply exceeded 20 kg. Fed-1, soil amendment might be necessary to fulfill plant requirement.

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كفاءة استخدام التسميد الفوسفاتي الأرضي والورقي تحت مستويات مختلفه من السماد النيتروجيني على انتاجية محصول البطاطس.

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الملخص العربى

اجرى هذا البحث بهدف دراسة تأثير التفاعل المشترك للتسميد الفوسفاتي والنيتروجينى على بعض صفات النمو ومحصول الدرنات وجودتها لصنف البطاطس دايمونت تحت ظروف الأراضى ذات رقم الحموضة المرتفعه . تضمنت معاملات التسميد الفوسفاتى الرش بعنصر الفوسفور بتركيزات ٥٠٠ أو ١٠٠٠ جزء/المليون فو٢أ٥ مع التسميد الأرضى بمعدلات صفر ، ٢٠ ، ٤٠ كجم فو٢ أ٥/فدان مقارنة بالمعدل الموصى به لتسميد البطاطس وهو ٦٠ كجم فو٢أ٥/فدان. واستخدم التسميد الأزوتى بمعدل ١٢٠ ، ١٨٠ كجم/فدان.

أدى التسميد النتروجينى بمعدل ١٨٠ كجم/فدان الى زيادة معنوية فى الوزن الطازج للمجموع الخضرى بحوالى ١١% وطول النباتات بحوالى ٦ % مقارنة باستخدام ١٢٠ كجم/فدان وذلك خلال عام ١٩٩٨ فقط . كما أدت زيادة التسميد النتروجينى من ١٢٠ الى ١٨٠ كجم/فدان الى زيادة محصول الدرنات بحوالى ١٠–١٣ % خلال عامى الدراسة . كما أدت نفس المعاملة الى ارتفاع النسبة المئوية لعنصر الفوسفور بالأوراق بحوالى ٤,٥ ، ١٣,٧ ، ٤,٨ % خلال عام ١٩٩٧ وبحوالى ٢,٣ ، صفر ، ٥ % خلال عام ١٩٩٨وذلك عند ٤٠ ، ٦٠ ، ٨٠ يوم من بدء الزراعة على التوالى . ونتيجة لزيادة معدل التسميد النتروجينى الى ١٨٠ كجم/فدان فقد زاد تركيز النتروجين (٢ – ٤ %) والبوتاسيوم (١ – ٣ %) بالدرنات بينما لم يتأثر محتوى الدرنات من المادة الجافة والنشا والفوسفور .

أدى التسميد الأرضى بمعدل ٦٠ كجم فو٢أ٥/فدان الى زيادة الوزن الطازج للمجموع الخضرى بنسب تتراوح بين ١٧ ــ ٣٤ % ، ١١ ــ ٢٢ % مقارنة ببقية معاملات التسميد الفوسفاتى خلال عامى ١٩٩٧ ، ١٩٩٨ على الترتيب ، بينما لم يتأثر الوزن الجاف للمجموع الخضرى بأى من معاملات التسميد الفوسفاتى ، كما أدى التسميد الأرضى بمعدلات أقل من ٤٠ كجم فو٢أ٥/فدان مع أى من معاملات التسميد الورقى الى قصر طول النباتات .

أدى التسميد الأرضى بمعدل ٤٠ كجم فو٢أ٥/فدان مع التسميد الورقى بتركيز ١٠٠٠ جزء/المليون فو٢أ٥ وكذلك التسميد الأرضى فقط بمعدل ٦٠ كجم فو٢أ٥/فدان الى انتاج أكبر محصول للدرنات وزيادة محتواها من عنصرى الفوسفور والبوتاسيوم، كذلك أدى التسميد الأرضى بمعدل ٤٠ كجم فو٢أ٥/فدان مع التسميد الورقى بتركيز ١٠٠٠ جزء/المليون فو٢أ٥ الى زيادة تركيز الفوسفور بالأوراق بعد ٤٠ ، ٦٠ ، ٨٠ يوم من الزراعة . كما أدى التسميد الأرضى بمعدل ٤٠ كجم فو٢أ٥/فدان الى أعلى زيادة فى نسبة البوتاسيوم بالدرنات بغض النظر عن تركيز السماد الورقى المستخدم .

ويمكن التوصية باضافة السماد النتروجينى بمعدل ١٨٠ كجم/فدان مع التسميد الفوسفاتى الأرضى بمعدل ٦٠ كجم فو٢أ٥/فدان أو التسميد الفوسفاتى الأرضي بمعدل ٤٠ كجم فو٢أ٥ مصحوبا بالتسميد الورقى بتركيز ١٠٠٠ جزء/المليون فو٢أ٥ وذلك للحصول على محصول مرتفع من الدرنات فى الأراضى ذات رقم الحموضة المرتفعه .