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Wheat Productivity as Affected by Different Fertilization Regimes

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THIS STUDY was conducted to determine the effect of balanced fertilization based on soil test for wheat plant grown in sandy soil. Two experiments were conducted during the seasons 2009/2010 and 2010/2011 at the research station of the Agricultural Research Center - Ismailia Governorate, Egypt. The design was randomized complete block with four replications and included seven treatments include control (T_0), farmers fertilization (T_1), recommended by Ministry of Agriculture MoA (T_2, T_3 and T_4), based on soil test (T_5) and (T_6) based on soil test plus micronutrients. The results in this study indicated that all NPK treatments had a positive effect on all parameters tested compared to control (no addition of fertilizers). The positive effects of the treatment are estimated in descending order: NPK by soil test +MN (**T_6**) > NPK by soil test (**T_5**)> NPK MoA (**T_2**)> fertilization by Farmers (**T_1**) NK MoA (**T_4**)> NP MoA (**T_3**)> control (**T_0**).NPK, depending on soil test plus foliar micronutrient (balanced fertilization) had also been shown to significantly increase plant nutritional status, grain yield, yield components and nutritional value of grain and straw. The highest values of nutrient were achieved by the balanced fertilization treatment NPK by soil test +MN (**T_6**) which were in the first season (116:41:55) and the second (122:45:65) N, P_2O_5 and K_2O, respectively. in combination with two times foliar feeding with chelated micronutrient compound).

Keywords: Balanced fertilization, Micronutrients, Sandy soil, Soil test, Wheat yield.

Introduction

Wheat is the most important cereal crops grown in Egypt. Area of wheat in Egypt in (1.52 million hectares) and grain production (8.8 million tons) (FAOSTAT, 2022) with an average yield per hectare of 6.55 tons, Fertilizers use by farmers is mostly based on fertilizer recommendations prepared by the Ministry of Agriculture (MoA). Application of fertilizer nutrients by the farmers is done without considering soil fertility status and nutrient requirements of crops which adversely affect soil and crops (Ray et al., 2000; Zhengxi, 2005). Intensive cultivation and, unbalanced fertilizer application are the main causes of depletion of macronutrients and micronutrients such as Zn, Mn and Fe (Mahajan et al., 2013). Given the high cost of fertilizers and the adverse effects of their overuse on the environment and soil health, appropriate fertilizer recommendations based on soil test values, residual effects and yield targets are of crucial importance.

In order to improve the profitability of agricultural lends under different soil and climate conditions, it is necessary to provide information on the optimal doses of fertilizers for each crops., to determine optimal fertilizer doses, is to apply fertilizers based on soil testing and correlation studies on crop behavior using a targeted yield approach to develop a relationship between crop yields on the one hand and soil and fertilizer inputs on the other (Ramamoorthy et al., 1967; Ramamoorthy & Velayutham, 1974; Singh et al., 2021). Ramamoorthy et al. (1967), first presented theory of formulating optimal fertilizer recommendations for specific yields was further modified as an "objective performance model". To achieve a specific crop performance objective, a certain amount of nutrients must be applied to

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the crop (Troug, 1960). This need for nutrients can be calculated taking into account the contribution of the nutrients available from the native soil and the fertilizer nutrients applied (SubbaRao & Srivastava, 2001).

The combined use of NPK fertilizers plays an important role in wheat production (Abd El-Samie et. al., 2018). The use of NPK in balanced amounts at the right time has a major impact on wheat yield. Different crop varieties, differ in their behavior in using NPK for grain production (Nisar et al., 1992; Malghani et al., 2010). Nitrogen plays an important role in growth processes, as it is an essential component of chlorophyll, proteins and nucleic acid (Marschner, 1995; TakujiOhyama, 2010). Phosphorus is essential for improving seed maturity and seed development (Ziadi et al., 2008). Both the P and K applications favored wheat grain and reduced its incorporation into wheat (Liakas et al., 2001), improved photosynthetic activity and transport to mature grains.

Egyptian farmers, use fertilizers at an accelerated pace especially N due to various factors such as increased area, increased fertilizer application rates for different crops and its depletion. As a result, Egypt is using high amount of chemical fertilizers, in particular fertilizers with N and potassium fertilizers are used in inadequate amounts. Soil fertility is declining due to the combined effects of increased pressure on land for more and more production and nutrient imbalance and deficiency of nutrient management. The aim of this study was to determine the optimal doses of NPK fertilizers for wheat production (cv. Sakha 94) based on soil tests in the East Delta, Ismailia, Egypt. As the soil is loamy sand an additional treatment using micronutrients was added.

Materials and Methods

A field experiment was carried out in Ismailia Agricultural Training Center, Ismailia governorate, during two successive winter seasons to study the influence of N P K recommendation based on soil testing on yield and yield components of wheat (cv. Sakha 94).

Soil samples were taken before seeding to test physical and chemical properties (Table 1). It shows that soil was low in almost all essential nutrients.

Experimental design and procedure

The experimental design used was randomize complete block with four replicates and seven treatments in each block.

Soil was ploughed using a chisel plough, leveled by wooden leveler and divided into experimental units. Plot area was 27m^2 (6m long and 4.5m wide). Every plot contained 30 rows each of 20 cm width. Wheat grains were sown on Dec.3 in 1st season and Nov.26 in 2nd season, at the rate of 60kg/fed. (Fed=Feddan = 4200m^2) by hand drilling in rows.

TABLE1. Treatments layout in two seasons

Code	First Season	Second season
	Treatment	
T_0	Control (no addition)	Control (no addition)
T_1	N : P_2O_5 : K_2O Farmer's Fertilization 70 : 15 : 24kg/fed.	N : P_2O_5 : K_2O Farmer's Fertilizer 70 : 15 : 24kg/fed.
T_2	N :P_2O_5 : K_2O recommended by Ministry of Agriculture 120 : 22 : 24kg/fed.	N : P_2O_5 : K_2O recommended by Ministry of Agriculture 120 : 22 : 24kg/fed.
T_3	N : P_2O_5 recommended by Ministry of Agriculture 120 : 22kg/fed.	N : P_2O_5 recommended by Ministry of Agriculture 120: 22kg/fed.
T_4	N : K_2O recommended by Ministry of Agriculture 120 : 24kg/fed.	N : K_2O recommended by Ministry of Agriculture 120 : 24kg/fed.
T_5	N : P_2O_5 : K_2O 116 : 41 : 55 kg/fed. based on soil test	N : P_2O_5 : K_2O 122 : 45 : 65kg/fed. based on soil test
T_6	N : P_2O_5 : K_2O soil test + micronutrients 116 : 41 : 55kg/fed.	N : P_2O_5 : K_2O soil test + micronutrients 122 : 45 : 65kg/fed.

Nitrogen doses were added in the form of ammonium nitrate (33% N) in three equal splits (at planting, 30 and 60 days after sowing). Phosphorus dose was added in the form of super phosphate (15.5% P_2O_5), at sowing. Potassium was added in the form of potassium sulfate (50% K_2O), in two equal doses at sowing and 30 days from sowing. Micronutrient treatments were 1.5g/L in the form of multi chelated micronutrients compound (3% Fe, 3% Zn and 3% Mn) and sprayed twice. The first and second spray was carried out in 350 and 400L/fed. at 50 and 65 days after sowing, respectively (Ankerman & Large, 1974).

Chemical analysis

Soil testing

Soil samples were analyzed for texture with a hydrometer (Bouyoucos, 1951), for pH and electric conductivity (EC) using water extract method (1 soil: 2.5 water) (Jackson, 1973), total calcium carbonate ($CaCO_3$%) by calcimeter method as described by Alison & Moodle (1965), and for organic matter (O.M %) content was determined using potassium dichromate (Chapman & Pratt, 1978). Phosphorus was extracted using sodium bicarbonate (Olsen et al., 1958). Potassium, calcium, Magnesium and sodium were extracted using ammonium acetate (Jackson, 1973). Iron, manganese, zinc and copper were extracted using DTPA (Lindsay & Norvell, 1978).

Calculation of the rate nitrogen, phosphorus and potassium application

The following calculation steps for determination of the rate of NPK application from mineral fertilizers (Fertilizer Requirement FR), according to Project Optimization of Fertilizer Use (NRC):

$$\mathbf{FR} = \boldsymbol{NR} - (\mathbf{NS} + \mathbf{NO} + \mathbf{NW}) * \mathbf{100/FUE}$$

where, FR= fertilizer removal of the crop (kg/fed), NR= nutrient requirement of N or P_2O_5 or K_2O kg/ ton of yield (grain and straw) x expected (target yield), NS= nutrient from the soil, kg/fed, NO= nutrients from organic fertilizer, kg/fed, NW= nutrient from irrigation water, kg/fed, FUE= fertilizer use efficiency %.

Plant analysis

A sample of 10 plants /plot was randomly taken at 90 days after sowing to determine Dry weight per plant (g), wheat shoots samples were analyzed for macro and micronutrients.

Plant samples were digested using an acid mixture consisting of nitric, perchloric and sulfuric acids in the ratio of 8:1:1 (v/v), respectively (Chapman and Pratt, 1978). Nitrogen (N) was determined in the dry plant samples using the boric acid modification described by Ma & Zuazage (1942), and distillation was done using Gerhardt apparatus. Phosphorus was photometrically determined using the molybdate vanadate method according to Jackson (1973). Potassium, calcium and sodium were determined using flame photometer (Genway). Mg, Fe, Mn, Zn and Cu were determined using the Atomic absorption spectrophotometer (Perkin Elmer 1100 B). The soil data were evaluated using the criteria published by Ankerman & Large (1974), as well as Silvertooth (2001), whereas, the leaf analysis data were evaluated according to the criteria reported by Jones et al. (1991).

At maturity, i.e. 145 and 150 days (April 18th and 26th in 2009/2010 and 2010/2011 seasons) respectively, after sowing the plants were harvested. A sample of one m^2 was taken to determine the number of spikes per m^2 ,number of grains per spike, spike length, in (cm), weight of grains per spike (g), 1000 grains weight (g), grain yield (ton/ha) and straw yield (ton/ ha). Grain and straw yield from three rows were harvested and weighed in each experimental plot.

Statistical analysis

The obtained data were subjected to the analysis of variance of randomized complete block design (RCBD), Every treatment was repeated four times, according to Snedecor & Cochran (1990) where the means of different treatments were compared using the least significant difference (L.S.D) test at 5% probability level.

Results and Discussion

Soil testing

According to the evaluation values available for the physical and chemical characteristics of the soil by, data presented in Table 2 (taken before sowing), showed that the soil was loamy sand in texture, high value of pH, while the total value to $CaCO_3$ tended to be medium, and electric conductivity (E.C) and organic matter (O.M) were low. In addition, content of the soil from N and P were ranged between low and medium, also K, Ca, Mg, Na, Fe, Mn, Zn and Cu, ranged between low and very low content. Based on their values and the removal, the doses of nitrogen, phosphorus and potassium (NPK) were calculated according for treatment of soil testing, (TS – table) were in the first season (114: 41: 55) and the second (122: 45: 65) N, P_2O_5 and K_2O, respectively.

Dry weight of shoots at 90 DAS (g/plant)

Application of NPK based on soil testing+ foliar micronutrients (T_6) gave the highest significant increments in dry weight in 1st and 2nd seasons, (table 2). Treatments based on Soil testing (T_5 and T_6) showed increase over the treatment recommended by the Ministry of Agriculture (T_2) in dry weight (11.6%), N- content (18.7%), P-content (40.6%), K-content (33.8%), Fe- content (14.7%), Mn- content (26.4%) and Zn- content (36.6%) in average of the two seasons. The treatments with low quantities or with imbalanced quantities (T_0 – T_1 – T_3 – T_4) showed low dry matter and low nutrient contents in 2009/2010 and 2010/2011 (Table 3).

These results indicate the importance of soil testing for wheat plants under conditions of these newly reclaimed loamy sandy soils, which are deficient in nutrients (Table 2). Increases in the above parameters when using NPK based on soil tests or NPK based on soil tests + micronutrients may be due to increases in nutrient absorption resulting from the availability of more and this probably promoted the well-developing of the root system in the upper zone.

Macronutrients content of wheat shoots at 90 DAS (mg/plant)

Compared with the control treatment Nitrogen content was significantly increased as a response to application of different NPK treatments. Phosphorus content in wheat shoot significantly increased with fertilizer of NPK (T_6). The most increment in K content in the shoot was obtained by the T_5 and T6 treatments. From the above mentioned results, it could be concluded that NPK treatments with optimized fertilizer to wheat plant increased the uptake N, P and K in wheat shoots at 90 days after sowing (Table 3).

Micronutrients content of wheat shoots at 90 DAS (µg/plant)

Results in Table 3 show that, the highest values for Fe, Zn and Mn contents in wheat shoots were determined by the NPK application with soil test + micronutrients (T_6). From the above mentioned results, it could be concluded that NPK treatments to wheat plant increased the contents Fe, Zn and Mn in wheat shoots at 90 days after sowing as compared with untreated plants (El-Fouly & El-Sayed, 1997; Duncan et al., 2018 a,b).

TABLE 2. Physical and chemical characteristics of soil (0 – 50cm depth) before sowing for 2009/2010 and 2010/2011 winter seasons

Characteristics	Oct. 2009 (2009/2010 season)		Oct. 2010 (2010/2011 season)	
Texture	Loamy Sand			
E.C dS/m	0.18		0.18	
pH	9.02		8.94	
$CaCO_3$ %	3.47		3.50	
Organic Matter %	1.05		1.10	
N %	0.015		0.013	
Available macronutrients mg/100g soil				
		Evaluation		Evaluation
P	1.5	M	0.74	L
K	12.6	L	4.83	vL
Na	4.6	L	4.4	L
Ca	450	H	290	H
Mg	15.1	L	12.8	L
Available micronutrients (ppm)				
Fe	2.24	vL	1.65	vL
Mn	0.18	vL	0.11	vL
Zn	0.39	vL	0.17	vL
Cu	0.16	vL	0.18	vL

H = High M = Medium L = Low vL = Very low

TABLE 3. Dry weight and macro-micronutrients content of wheat shoot as affected by different NPK doses and soil testing at 90 days after sowing

	Shoot DW (g/plant)		N (mg/plant)		P (mg/plant)		K (mg/plant)		Fe (µg /plant)		Mn (µg /plant)		Zn (µg /plant)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control (natural soil (T_0)	0.37	0.86	4.17	9.61	0.6	1.81	11.26	25.9	11.15	25.65	9.88	12.84	8.92	11.58
Farmer's Fertilizer (T_1)	1.07	2.74	19.05	43.81	1.57	3.6	27.33	62.87	41.91	71.25	18.58	24.15	43.38	52.05
NPK, Ministry. Agric. (T_2)	1.39	3.2	22.43	51.6	1.93	4.36	33.62	77.33	52.11	90.59	20.58	26.75	52.57	63.08
NP, Ministry. Agric. (T_3)	0.86	1.98	14.95	34.39	1.47	3.39	23.31	53.62	63.62	63.62	12.58	16.36	26.88	34.94
NK, Ministry. Agric. (T_4)	0.99	2.27	21.36	49.13	0.79	1.38	23.67	54.41	27.66	62.06	14.09	18.32	39.25	51.02
NPK soil testing (T_5)	1.43	3.29	23.49	54.02	2.45	5.64	36.48	83.91	53.29	93.79	23.12	30.06	61.11	85.55
NPK soil testing + micro. (T_6)	1.67	3.85	29.76	68.45	2.95	6.67	53.46	122.96	64.76	116.56	28.9	37.57	77.38	92.85
$LSD_{at\ 0.05}$	0.27	0.61	9.62	22.14	0.53	1.22	14.59	33.56	19.97	25.96	8.86	11.52	20.57	26.74

Yield and yield components

Application of NPK based on soil testing had a significant effect on plant height (cm), spike number/ m^2, spike length (cm), grains number/spike, grains weight/spike (g), 1000-grain weight (g), grains yield and straw yield (Table 4). Fertilizing wheat plants with 120kg N/fed.+ 22kg P_2O_5 /fed. + 0kg K/fed. (T_1) produced the highest increase for plant height, as compared with control and other treatments. While, the highest values for grains number/spike, spike length and 1000-grain weight, grain and straw yield/ha were obtained by the NPK application of (116: 41: 55) and (122: 45: 65) N, P_2O_5 and K_2O with micronutrients foliar spray (T_6) in 1st and 2nd season, respectively. However, control treatment (T_0) gave the highest value for spike number/m^2. The lowest values of grain and straw yields were resulted from the untreated plants (control) The results obtained are in agreement with El-Fouly et al. (2012) on maize and El-Saady et al. (2014) on groundnut, who found that and fertilizer use must be in balanced form depending on soil test. Where, applying a balanced fertilization optimizing fertilizer use, through recovering the nutrients depleted from the soil by plants.

Grain chemical compositions at harvest

It is obvious that nitrogen, Phosphorus and Potassium contents were significantly increased as a response to application of different NPK treatments. Maximum increment in N, P and K content in the shoot was obtained by the T_6 and T_5. At harvest stage the micronutrient content of the grain i.e. Fe, Mn, and Zn revealed the same trend of treatments in the same order of: NPK based on soil test +MN (T_6)> NPK beads on soil test (T_5)> NPK MoA (T_2)> fertilization by Farmers (T_1) NK MoA (T_4)> NP MoA (T_3)> control (T_0), The increments in micronutrients measured in wheat grains as a result of balanced fertilization is in agreement with the findings of Salim & Raza (2020), El-Nasharty et al. (2021) who reported that the decreasing of one essential nutrient may limit the consumption of another nutrient (Table 5).

Protein content of grains showed significant response to NPK application treatments (Table 5). NPK soil test + MN (T_6) gave the highest value of wheat protein of grains content followed by NPK soil test (T_5) as compared with other treatments and control. However, application of NPK soil test (T_5) was attained the highest value of wheat grains in P and K content in the second season followed by (T_5) in first season. While, the highest value in Fe, Mn, Zn and protein contents of wheat grain were obtained by application of NPK with soil test + micronutrients foliar spray (T_6).

TABLE 4. Effect of NPK on yield and yield component of wheat plants

	Plant height (cm)		No. of spike/ m^2		No. of grains / spike		Spike length (cm)		Grains weight/spike (g)		1000- grains weight (g)		Grains yield (ton/ha)		Straw yield (ton/ha)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control (natural soil (T_0)	46.3	38.8	357.3	298.3	8.3	6.9	3.8	3.1	0.24	0.20	34.33	28.99	1.24	1.03	1.27	1.05
Farmer's Fertilizer (T_1)	89.3	74.6	476.5	397.5	24.9	28.7	7.8	7.9	1.04	0.87	42.33	30.31	4.97	4.14	6.06	4.83
NPK, Ministry. Agric. (T_2)	92.3	77.1	449.3	434.3	35.2	29.6	9.2	7.8	1.24	1.03	52.00	34.58	5.47	4.56	6.17	5.14
NP, Ministry. Agric. (T_3)	93.3	80.2	517.9	419.2	22.2	18.8	9.0	7.5	0.85	0.71	42.33	37.77	4.45	3.71	6.73	3.61
NK, Ministry. Agric. (T_4)	91.0	75.8	473.1	394.2	24.6	20.8	7.8	6.5	1.02	0.85	44.67	38.58	4.83	4.03	5.05	4.20
NPK soil testing (T_5)	93.0	77.5	532.5	444.2	32.0	26.7	8.8	9.1	1.51	1.26	52.33	40.87	6.63	5.53	6.76	5.63
NPK soil testing + micro.(T_6)	96.0	82.3	518.5	420.7	43.7	37.3	9.5	9.2	1.49	1.29	53.67	42.57	7.46	6.25	6.96	5.03
LSD $_{at\ 0.05}$	7.87	6.7	73.82	61.8	7.72	6.4	1.04	2.15	0.20	0.09	3.34	2.78	1.13	2.03	1.36	1.13

TABLE 5. Effect of NPK on grains dry weight (g/plant), macro-micro nutrients and protein content of wheat at harvest

	Grains DW (g/plant)		N (mg/plant)		P (mg/plant)		K (mg/plant)		Fe (µg /plant)		Mn (µg /plant)		Zn (µg /plant)		Protein (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control (natural soil (T_0)	0.25	0.21	05.00	06.05	0.71	0.59	01.78	02.41	15.81	19.20	02.51	03.06	7.80	09.36	11.46	09.59
Farmer's Fertilizer (T_1)	1.34	1.12	31.53	38.41	4.00	4.85	10.18	10.18	22.90	27.63	12.69	15.92	31.73	38.44	14.69	11.53
NPK, Ministry. Agric. (T_2)	1.84	1.53	42.05	50.12	5.52	6.62	12.88	15.62	26.98	32.41	18.13	22.23	45.21	54.65	17.69	12.09
NP, Ministry. Agric. (T_3)	1.46	1.22	32.88	39.60	4.44	5.33	10.33	13.20	20.71	25.21	13.83	16.81	35.61	42.61	14.06	11.67
NK, Ministry. Agric. (T_4)	1.41	1.18	31.00	37.20	4.13	5.40	9.30	11.40	24.80	30.05	13.00	15.66	42.41	51.00	13.69	10.77
NPK soil testing (T_5)	2.02	1.68	43.96	52.75	6.53	7.32	15.13	12.63	30.30	36.65	21.36	25.83	47.39	56.87	18.96	12.68
NPK soil testing + micro. (T_6)	2.03	1.69	42.50	61.60	5.71	7.58	13.09	16.22	37.48	45.09	23.68	28.56	55.03	66.09	19.33	13.93
LSD $_{at\ 0.05}$	0.39	0.40	10.98	13.18	1.25	2.48	3.15	3.78	6.42	10.81	3.63	6.36	11.88	14.43	2.73	2.28

Conclusions

The results of this study showed the insufficiency of the fertilizers recommendations applied by farmers and recommended by the Ministry of Agriculture for the sandy soil conditions under study, for N, P and K compared with using the balanced recommendation of fertilizers based on soil testing, whereas spraying with micronutrients for wheat grown on sandy soils that lack of nutrients achieve the highest yield and the best quality.

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Data availability: All data generated or analyzed during this study are included in this published article (and its Supplementary information files).

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إنتاجية القمح وتأثرها بأنظمة التسميد المختلفة

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أجريت هذه الدراسة لمعرفة تأثير التسميد المتوازن على أساس اختبارات التربة لنبات القمح المزروع في التربة الرملية. أجريت تجربتان خلال موسمي 2010/2009 و2011/2010 بمحطة البحوث التابعة لمركز البحوث الزراعية – محافظة الإسماعيلية، جمهوريه مصر العربيه. تم التصميم بالقطاعات الكاملة العشوائية بأربعة مكررات وتضمنت سبع معاملات. وأشارت نتائج هذه الدراسة إلى أن جميع معاملات NPK كان لها تأثير إيجابي على جميع الصفات المدروسه مقارنة بالكنترول (عدم إضافة الأسمدة). تم تقدير التأثيرات الإيجابية للمعاملات بترتيب تنازلي: NPK بناء على اختبارات التربة + العناصر الصغرى (MN) (T_6) > NPK بناء على اختبارات التربة (T_5) > NPK بناء على توصيات وزارة الزراعة (MoA) (T_2) > التسميد بواسطة المزارعين (T_1) > NK بناء على توصيات وزارة الزراعة (MoA) (T_4) > NP بناء على توصيات وزارة الزراعة (MoA) (T_3) > الكنترول (T_0) ، التسميد باستخدام NPK بناء على اختبارات التربة بالإضافة إلى العناصر الصغرى (التسميد المتوازن) يؤدي لزيادة ملحوظة في الحالة الغذائية للنبات وإنتاجية الحبوب ومكونات الإنتاج والقيمة الغذائية للحبوب والقش. وتم الحصول على أعلى قيم للعناصر الغذائية بالمعاملة المتوازنة NPK بناء على اختبارات التربة + العناصر الصغرى (MN) (T_6) والتي كانت في الموسم الأول (116 : 41 : 55) والثاني (122 : 45 : 65) $N : P_2O_5 : K_2O$. على التوالى بالإضافة للتسميد الورقي مرتين بمركب العناصر الصغرى المخلبيه.