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EFFECTS OF CHEMICAL AND BIOLOGICAL FERTILIZERS ON GROWTH, YIELD AND TUBER QUALITY OF POTATOES GROWN IN SANDY SOILS UNDER SEMI-ARID CONDITIONS

Al-Moshileh, A. M. and A. E. Moftah
Dept. of Plant Production and Protection, College of Agriculture and Veterinary Medicine, Qassim University, Saudi Arabia.
Buraydah B.O. Box: 1482
E.mail: amoshileh@hotmail.com

ABSTRACT

This field study was carried out, during fall seasons of 2002 and 2003, to evaluate the effect of chemical fertilizer (Sangral) and biofertilizer (Nitrobien) in different ratio (0/0, 100/0, 75/25, 50/50, 25/75 and 0/100% of Sangral and Nitrobien, respectively) on the growth, the yield and the chemical composition of potatoes. Results showed that nitrogen application increased vegetative growth and yield of new tubers. The addition of 25% of Nitrobien to 75% of the chemical fertilizer resulted in the highest values of growth parameters and yield as compared with all other treatments. Chlorophyll, N, P and K in leaves and total carbohydrate concentration in tubers were also increased by the addition of 25% of Nitrobien to the chemical fertilizer. This study indicated that the application of 25% of Nitrobien with 75% of Sangral in mixed form is the best treatment for potato growth and production in arid and semi-arid regions.

Keywords; (*Solanum tuberosum* L.), "Sangral", bio-fertilizer "nitrobine", Chlorophyll, N, P, K, total carbohydrates.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is considered as one of the most important vegetable crops in many areas of the world and there is a high demand for local market, processing and exportation. A great attention to the use of bioagriculture in potato production using organic fertilizers, in order to reduce water and soil contamination with biofertilizers, is considered recently.

One of the major concerns in today's world is the pollution and contamination of soil. The use of chemical fertilizers and pesticides has caused tremendous harm to the environment. Recently, intensive effort is being spent to minimize the amount of potato nitrogen fertilizers in order to decrease production cost and environment pollution without major reduction in tuber yield. Biofertilizers are environmentally friendly fertilizers and are used in most countries. Biofertilizers are organisms that enrich the nutrient quality of soil. The main sources of biofertilizers are bacteria, fungi and cyanobacteria (blue-green algae). The most striking relationship that these have with plants is symbiosis, in which the partners derive benefits from each other. Plants have a number of relationships with fungi, bacteria and algae, the most common of which are with mycorrhiza, rhizobium and cyanophyceae. These are known to deliver a number of benefits including plant nutrition, disease resistance and tolerance to adverse soil and climatic conditions. These techniques have proved to be successful biofertilizers that form a health relationship with the roots. Biofertilizers will help to solve such problems as increasing soil salinity and chemical run-offs from the agricultural fields. Thus, fertilizers are important if we are to ensure a healthy future for the generations to come.

Recent attention has been given to less pollution practices in modern agriculture. One of ways to reduce soil pollution is the use of biofertilizers which have been recommended by several investigators to substitute chemical fertilizer (El-Agory *et al.*, 1996 and Krishnamurthy *et al.*, 2001). The use of biofertilizers may have additional benefits such as nitrogen fixation, mobilizing phosphate and micronutrients through the production of organic acids and lowering soil pH (Saber, 1993). Microorganisms that make up the biofertilizer can secrete growth promoting factors such as gibberellins, cytokinines, and auxins (Ghosh *et al.*, 2000). The aim of the current study is to evaluate the efficiency of biofertilizer in minimizing chemical fertilization doses and investigate its effect on growth, chemical constituents and yield of potatoes.

MATERIALS AND METHODS

This field experiment was carried out during the autumn seasons of 2002 and 2003 at the Research Station of the College of Agric. and Veterinary Medicine, Qassim University, Saudi Arabia, to investigate the response of potato plants (Cv. Spunta) to chemical and bio-fertilizers added as mixed or separate fertilizer. The experimental soil was sandy with chemical and physical properties shown in Table 1. The experiment included 6 treatments arranged in a randomized complete block design with three replicates. Tubers were planted, 30 cm apart, in rows, 3 m length and 100 cm apart. The area of the experimental unit was 9 m^2 (3 × 3 m).

Table 1: Initial characteristics of the soil textures used.

Characteristics	Values
Particle size distribution(%)	
Coarse sand	50.20
Fine sand	39.50
Silt	3.60
Clay	6.60
Soluble cations(meq1^{-1})	
Ca^{++}	11.30
Mg^{++}	03.60
Na^{+}	17.70
Soluble anions(meq1^{-1})	
Cl^{-}	13.80
HCO 3^{-}	08.10
$SO^{=}$ 4	15.30
EC (dSm^{-1} at 25° C)	03.56
pH (paste)	8.10
Organic carbon	0.22

Chemical fertilizer (Sangral, ammonium sulphate 20% N) : biofertilizer (Nitrobien) ratios were as follows: 100:0, 75:25, 50:50, 25:75 and 0:0 (control) of chemical fertilizer (CF) : biofertilizer (BF), respectively. Nitrobien (*Azospirillum sp* + *Azobacter sp*) in the amount of 2.5 kg/ha was added before planting with one-third of the amount of Sangral (600 kg/ha). The rest of Sangral was divided into two equal portions and added at 30 days intervals at beginning of complete emergence. Sangral contains both macro and micro nutrients: 20% N (ammonium sulphate), 20% P (P_2O_5), 20% K, (K_2O), 0.40% S, 0.02% Mg (MgO), 70 ppm Fe, 14 ppm Zn, 16 ppm Cu, 42 ppm Mn, 22 ppm B and 14 ppm Mo. Other agricultural practices were followed as commonly recommended for potatoes.

Table 2: Initial characteristics of the irrigation water used.

Water characteristics	Values
EC (mmoh.cm^{-1})	1.80
Soluble cations(meql^{-1})	
Ca^{++}	8.00
Mg^{++}	3.20
Na^{+}	6.50
K^{+}	0.24
Soluble anions(meql^{-1})	
Cl^{-}	5.50
CO3	0.00
HCO3	3.10
SO4	5.00
PPM	1204
SAR	3.08
Water pH	6.90

Potato tubers cv. Spunta were planted on 15/9/2002 and 17/9/2003, while harvesting was done on 20/1/2003 and 24/1/2004, for the two experiments respectively. Drip irrigation was used. The amount of irrigation water applied was to 12 ml per plot per every irrigation time. The chemical composition of irrigation water is given in table 2. Also, fertilization was applied as recommended by the ministry of Agriculture, so, the total dose of 200 kg K_2O/ hectare as potassium sulfate (40%), 300 kg P_2O_5/ hectare as superphosphate (20%), and a dose of 300 kg N/hectare as urea were applied.

Data on plant height, number of aerial stems, number of leaves per plant, and dry weight of plant parts (after oven-drayed at 70°C to constant weight) were recorded at ninety days after planting. Chlorophyll was determined according to Wettestein (1957).

Total nitrogen, phosphorus, and potassium were determined in the ground dry materials. The samples were digested in a mixture of sulfuric acid, salicilic acid and hydrogen peroxide according to Linder (1944). For determination of total N, the modified Microkjeldahl apparatus was used

(Pregl, 1945). Phosphorus was determined colorimetrically (Jackson, 1967), while potassium was determined by using the flamephotometer.

At harvest, tubers were collected, weighed, counted and graded into three size categories according to their diameters (above 7, 4-6.9 and less than 4cm) and then each grade was weighed separately. Dry matter percentage of tubers was determined after oven-drying at 105°C until constant weight. Total carbohydrates were determined in tubers following the method of Buysse and Merckx (1993).

All data were statistically analyzed according to Snedecor and Cochran (1980) with the aid of COSTAT computer program for statistics. Differences among treatments were tested with LSD at 5% level of significance.

RESULTS AND DISCUSSION

1-Growth parameters

Data recorded in Table 3 indicate that plant height, number of stems per plant, number of leaves per plant, and dry weight of shoots were increased significantly by nitrogen fertilization as compared with control plants (0/0 treatment). The best results were obtained with the treatment of 75/25, at which all growth parameters recorded greatest values compared with all the other treatments. All growth values tended to decrease as the chemical fertilizer portion was reduced. This was true at both seasons.

Table 3. Effect of chemical and biofertilizers on vegetative growth of potato plants.

Treatments (CF/BF)%[1]	Plant height (cm)	No. Stems /plant	No. leaves /plant	Shoot dry weight (g)
		Season (2002)		
0/0	28.44 d[2]	3.22 c	32.12 d	07.26 d
100/0	52.81 a	6.12 a	66.24 a	14.22 b
75/25	56.65 a	6.64 a	75.14 a	18.45 a
50/50	46.45 b	5.14 b	60.34 b	12.10 b
25/75	40.33 b	4.88 b	54.12 b	09.56 c
0/100	34.82 c	4.50 b	48.06 c	09.12 c
		Season (2003)		
0/0	22.21 d	2.11 c	41.20 d	04.16 d
100/0	43.33 a	5.16 a	65.45 a	12.62 b
75/25	48.05 a	6.01 a	70.22 a	14.47 a
50/50	36.41 b	3.33 b	56.64 b	11.14 b
25/75	32.18 b	3.16 b	46.87 b	08.44 c
0/100	28.55 c	2.98 b	41.26 c	08.24 c

[1] CF = chemical fertilizer, BF = biofertilizer.
[2] Values represent means of 3 measurements. Means followed by the same letters within a column are not significantly different using LSD (0.05) comparisons.

The present results may confirm the study of Abd-El-Hafez *et al* (2001) on corn, Sundaravelu and Muthukrishinan (1993) on radish and Hanafy *et al.* (2000) on lettuce who reported that biofertilizer treatments increased significantly the height, the leaf area, and the dry weight of treated plants. In a recent and similar study by Al-moshileh, 2004 on spinach, he reported that vegetative growth enhanced when plants were provided with mixture of chemical and biofertilizer, compared with control or both fertilizers as single treatments. The increased growth variables resulted from nitrogen fertilization may be attributed to the increase in cell division and elongation which reflected increases in plant height and dry matter accumulation (Sharief *et al.*, 1998 and Hamed, 1998). Moreover, increases in growth parameters due to biofertilizer application may be attributed to the positive effect of bacterial inoculation and living organisms, exist in the biofertilizer, on nitrogen fixation and endogenous phytohormones such as indole-acetic acid, gibberellins and cytokinins which play an important role in the formation of new cells and plant tissues (Salisbury and Ross, 1992).

2-Yield components

Data show that the number of tubers and tuber weight per plant were increased significantly by nitrogen application as compared with the control (Table 4). The highest values of both parameters were recorded at 75/25, as compared to the other treatments. At such treatment, number of tubers per plant was more than 2.5 times as much as control plants, while 100/0 treatment increased the number of tubers by about 2.2 times of the control. Weight of tubers per plant followed the same trend as that recorded for the number of tubers. The most increase in tuber weight per plant was recorded at 75/25 treatment, which caused an increase of about 3 times more than control plants. It is obvious that size of tubers was increased significantly by the addition of 25% of the nitobien biofertilizer to the chemical fertilizer. In this concern, 75/25 treatment produced nearly 37% large size grade and 39% medium size grade tubers, while the small size grade was the lowest percentage value (24%) among all treatments. Results were comparable at both seasons.The increment in tuber yield and size of potato plant by the presence of biofertilizer with the chemical fertilizer may be attributed to the increased fixation of nitrogen and enhancing the photosynthesis. Consequently, increased photosynthates and carbohydrate formation and translocation from the aboveground parts to the under ground parts, leading to increasing the tuber size. Besides the influence of phytohormone by biofertilizer which result in increasing tuber production per plant and tuber size. These results are in a full agreement with those reported by Sultan *et al.* (1994), Singh *et al.* (1993) and Al-Moshileh and Motawei (2003). The present data are in agreement with those reported by El-Akabawy *et al.* (2000) who mentioned that cotton yield was increased significantly through the use of the biofertilizer Nitrobien. Dry matter accumulation in tubers was increased significantly in fertilized, compared with unfertilized plants (Fig. 1). The highest value of dry matter percentage was recorded at 75/25 treatment compared with the other fertilizer applications. At this treatment, dry mater percent was 2.5 as much as that in control tubers with 0/0 treatment. This accumulation of dry matter may be due to the positive effect of biofertilizer on nutrient uptake and solute accumulation in new tubers. In this connection, Reinink *et al.* (1987) assumed that a higher percentage of dry weight was associated with higher concentrations of organic solutes such as carbohydrates, amino acids and proteins. The present study shows that dry matter accumulation in tubers was associated with high concentration of carbohydrates.

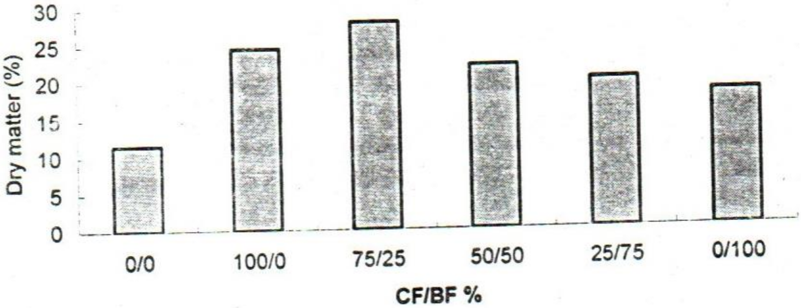

Fig. 1. Effect of chemical fertilizer (CF) and biofertilizer (BF) on dry matter% of potato tubers.

Table 4. Effect of chemical and biofertilizers on yield and quality of tubers

Treatment (CF/BF)%[1]	No. tubers /plant	Tuber wt (g) /plant	Size grade			size grade%		
			S[2]	M	L	S	M	L
			Season (2002)					
0/0	5.14 c[3]	518 e	2.64 d	1.35 c	1.15 c	51 a	27 c	22 bc
100/0	11.72 a	1322 b	3.41 b	4.62 a	3.69 b	29 c	39 a	32 a
75/25	13.15 a	1612 a	3.20 b	5.11 a	4.84 a	24 c	39 a	37 a
50/50	10.72 a	1015 c	4.16 a	3.26 b	2.80 b	41 b	32 b	27 b
25/75	8.12 b	986 c	3.21 b	3.16 b	1.75 c	40 b	40 a	20 cd
0/100	6.15 c	745 d	3.01 c	2.06 c	1.08 c	48 b	34 b	18 d
			Season (2003)					
0/0	4.66 c	485 e	2.44 d	1.27 c	1.23 c	49 a	25 c	26 b
100/0	10.52 a	1109 b	3.17 b	3.95 a	3.48 b	30 c	37 a	33 a
75/25	12.22 a	1365 a	3.21 b	4.67 a	4.62 a	26 c	37 a	35 a
50/50	11.13 a	1125 c	3.98 a	3.18 b	2.66 b	41 b	32 b	27 b
25/75	7.34 b	977 c	3.11 b	3.00 b	1.44 c	41 b	42 a	17 c
0/100	5.045 c	718 d	2.88 c	2.26 c	1.11 c	46 b	36 b	18 c

[1] CF = chemical fertilizer, BF = biofertilizer.
[2] S = small, M = medium, L = large size.
[3] Values represent means of 6 measurements. Means followed by the same letter(s) within a column are not significantly different using LSD $_{(0.05)}$ comparisons.

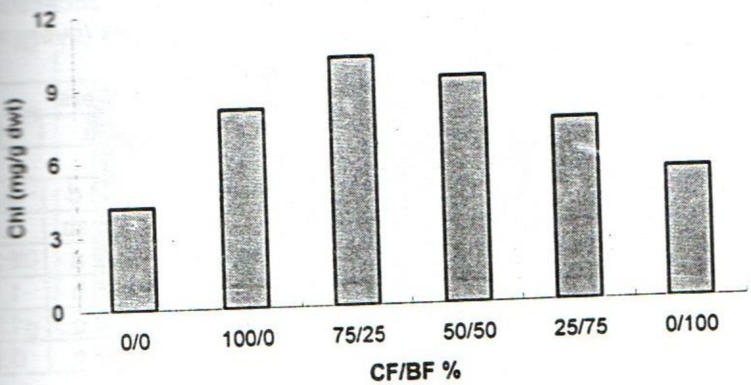

Fig. 2. Effect of chemical fertilizer (CF) and biofertilizer (BF) on total chlorophyll of potato leaves.

3- Chemical analysis

Chlorophyll. At both seasons, total chlorophyll was increased significantly by nitrogen treatment as compared with control plant (Fig. 2). The highest value of total chlorophyll was recorded at 75/52 treatment followed by 50/50 treatment, while the lowest content was measured at control (0/0) treatment. The increased content of chlorophyll with the cytokinin in presence of biofertilizer inoculation may be due to increased endogenous plant tissues (Hanafy, 2000). Cytokinin is known to increase chlorophyll synthesis and delay senescence of plant organs (Taiz and Zeiger, 2002). In an early study, Ghosh *et al.* (2000) found that cytokinin was found to increase chlorophyll formation in plant leaves.

Elemental concentration. Data recorded in Table 5 show that N, P and K concentrations in shoots and tubers were increased significantly by chemical fertilization as compared with the control. Biofertilizer application with chemical fertilizer enhanced the concentration of all elements. It is obvious that the highest values were obtained by 75/25 treatment at which N, P and K in shoots were increased by about 190, 260 and 60% more than control treatment, while the corresponding increases in tubers at the same treatment were 125, 220 and 79%, respectively. Results of the second season followed the same trend as that obtained at the first one. These results are in agreement with those obtained by Lin *et al.* (1983) who reported that fertilization with Azospirillum increased elemental concentrations in *Zea mayz* and Sorghum plant tissues. The increase in elemental concentration by the application of biofertilizer with the chemical fertilizer could be attributed to the enhancing effect of the biofertilizer on endogenous phytohormones witch play an important role in the formation of a big root system and hence, increase the nutrient uptake and photosynthesis as well as carbohydrates translocation (Sharief *et al.*, 1998).

Table 5. Effect of chemical and bio fertilizers on the concentration of nutrient elements (%) of potato leaves and tubers (every value is a mean of 3 replicates).

Treatments (CF/BF)%[1]	Leaves			Tubers		
	N[2]%	P%	K%	N%	P%	K%
Season (2002)						
0/0	1.06 d[3]	0.11 d	0.86 c	0.64 d	0.09 d	0.65 c
100/0	2.68 b	0.32 b	1.46 a	1.21 b	0.28 ab	1.09 b
75/25	3.12 a	0.40 a	1.65 a	1.45 a	0.32 a	1.28 a
50/50	2.44 bc	0.31 b	1.32 a	1.20 b	0.25 b	1.11 b
25/75	2.11 c	0.28 c	1.14 b	1.16 bc	0.20 c	1.05 b
0/100	2.04 c	0.26 c	1.08 b	1.08 c	0.18 c	0.96 b
Season (2003)						
0/0	1.01 d	0.09 d	0.66 c	0.44 d	0.09 d	0.67 c
100/0	2.56 b	0.28 b	1.12 b	1.11 b	0.24 b	1.05 b
75/25	3.08 a	0.38 a	1.58 a	1.35 a	0.31 a	1.18 a
50/50	2.24 b	0.29 b	1.22 b	1.10 b	0.26 b	1.14 a
25/75	2.23 c	0.20 c	1.16 b	1.11 b	0.19 c	1.01 b
0/100	1.98 c	0.18 c	0.88 c	0.78 c	0.17 c	0.92 b

[1] CF = chemical fertilizer, BF = biofertilizer.
[2] N = nitrogen, P = phosphorous, K = potassium.
[3] Values represent means of 3 measurements. Means followed by the same letter(s) within a column are not significantly different using $LSD_{(0.05)}$ comparisons.

Total carbohydrates. Carbohydrate concentration was increased in a similar way as dry matter accumulation (Fig. 3). As indicated in the figure, the combined data of both seasons showed that, carbohydrates were increased significantly by the presence of 25% Nitrobien with the chemical fertilizer. It is obvious that 75/25 treatment was the best regarding the increasing carbohydrates in tubers compared to the other treatments. The increase in tuber carbohydrates under this treatment was about 25% more than control tubers. The ability of the biofertilizer to increase carbohydrate concentration in tubers may be attributed to its positive effect on photosynthesis and photosynthetase translocation from shoots to the newly produced tubers. Al-Moshileh and Motawei (2001) reported that increasing in vegetative growth will result in high potato tuber weight. In a similar study, Hanafy *et al.* (2000) found that Nitrobien biofertilzer caused a significant increment in total carbohydrate concentration in treated-lettuce plants.

on total carbohydrates of potato tubers

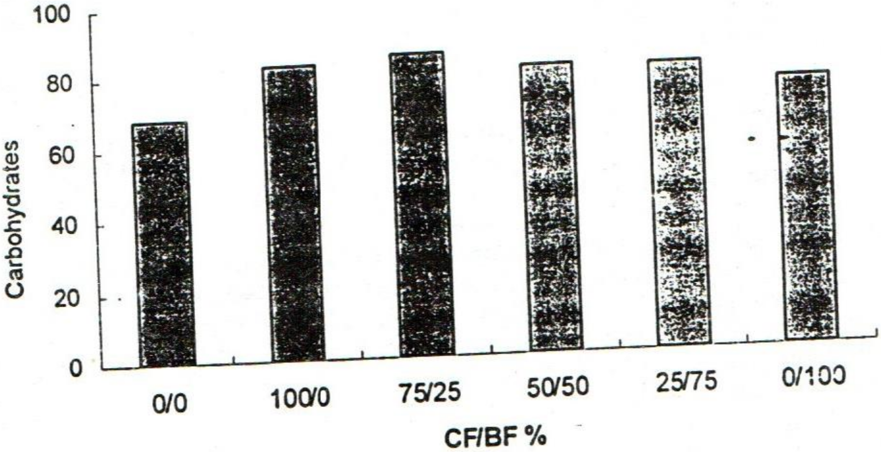

Fig. 3. Effect of chemical fertilizer (CF) and biofertilizer (BF) on total carbohydrates of potato tubers.

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تأثير التسميد الكيماوي والحيوي على نمو، كمية وجودة درنات البطاطس النامية في تربة رملية تحت ظروف بيئية شبه جافة

عبد الرحمن بن محمد المشيلح، أنصاري إدريس مفتاح
قسم إنتاج النبات ووقايته -كلية الزراعة والطب البيطري – جامعة القصيم - المملكة العربية السعودية – بريدة ص.ب. ١٤٨٢

أجريت هذه التجربة الحقلية خلال الموسم الخريفي لعامي ٢٠٠٢ و ٢٠٠٣ وذلك بهدف تقييم تأثير ٦ معدلات من التسميد الكيماوي والحيوي (٠/٠، ١٠٠/٠، ٢٥/٧٥، ٥٠/٥٠، ٧٥/٢٥ و ٠/١٠٠% من السماد الكيماوي سانجرال و المخصب الحيوي نيتروبين) على التوالي وذلك على نمو وإنتاجية نباتات البطاطس صنف سبونتا. كما اشتملت الدراسة على تأثير التسميد على نوعية الدرنات ومحتواها الكربوهيدراتي ونسبة المادة الجافة بها. وقد أوضحت النتائج ما يلي:

١-أدى التسميد بنوعيه إلى زيادة نمو المجموع الخضري متمثلا في طول النباتات، عدد الأفرع، عدد الأوراق والوزن الجاف للمجموع الخضري لنباتات البطاطس.
٢-أدت إضافة نسبة ٢٥% من النيتروبين مع سانجرال الى زيادة فاعلية السماد الكيماوي حيث كانت المعاملة ٢٥/٧٥ من أفضل المعاملات تاثيراً على قياسات النمو الخضري.
٣-إزداد تركيز اليخضور (الكلوروفيل) مع التسميد وخاصة المعاملة ٢٥/٧٥ التي أدت إلى زيادة تركيز الصبغة في الأوراق زيادةً معنوية.
٤-دلت النتائج على زيادة تركيز كل من النيتروجين، الفوسفور والبوتاسيوم زيادةً معنوية خاصة عند المعاملة ٢٥/٧٥ مقارنة بالمعاملات الأخرى.
٥-أدى التسميد الحيوي بنسبة ٢٥% إلى زيادة حجم الدرنات ووزنها الجاف وزيادة محتواها من الكربوهيدرات وأيضاً زيادة النسبة المئوية للمادة الجافة فيها.

لقد دلت هذه الدراسة على إمكانية استخدام المخصب الحيوي نيتروبين بنسبة ٢٥% مخلوطاً مع السماد الكيماوي سنجرال بنسبة ٧٥% في إنتاج نباتات بطاطس قوية وذات محصول عالٍ وحجم درنات مناسب مع ارتفاع نسبة الكربوهيدرات فيها وبذا يمكن الإقلال من التلوث البيئي الناتج عن زيادة استخدام الأسمدة الكيماوية.