EFFECT OF MINERAL AND BIOFERTILIZERS ON GROWTH, YIELD, TUBER ROOT QUALITY AND STORABILITY OF SWEET POTATO PLANTS GROWN IN SANDY SOIL

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ABSTRACT

This work was carried out during the two successive summer seasons of 2003 and 2004 at El-Khattara Experimental Farm, Fac. Agric., Zagazig University, to evaluate the effect of single and combined applications of mineral and biofertilizers on growth, yield and its components, tuber root quality and storability of sweet potato cv. Mabroka under sandy soil conditions.

Nitrobein (Nr) was used as a nitrogen fixing bacteria in addition to phosphorein (Pr) as a phosphate dissolving bacteria. Fertilization of sweet potato plants with NP mineral fertilizers at 100% of the recommend rates (80 N + 60 P_2O_5) kg/*fed* , or N + P fertilizers combined with the biofertilizers phosphorein (Pr) or nitrobein (Nr) at different rates and combinations of 80 N + 30 P_2O_5 + 0.6 Pr , 80 N + 15 P_2O_5 + 1.2 Pr, 40 N + 60 P_2O_5 + 1 Nr , 20 N + 60 P_2O_5 + 2 Nr , 40 N + 30 P_2O_5 + 1 Nr + 0.6 Pr and 20 N + 15 P_2O_5 + 2 Nr + 1.2 Pr (kg/ fed) *,* significantly increased plant growth characters (vine length, number of both branches and leaves / plant and dry weight of different plant parts, number of tuber roots/ plant and total yield , comparing with using biofertilizers alone .

In general, fertilization of sweet potato with N+P at *80 kg N +60 kg P_2O/ fed or the* combinations of N+P and Nr +Pr at different rates gave the highest values of average tuber root weight, yield /plant and yield of oversized, marketable and total yield, whereas, Nr and Pr at different rates without mineral fertilizers gave the lowest values of yield and its components.

However, inoculation of sweet potato plants with biofertilizers without mineral fertilizers, gave tuber roots with good quality and storability concerning TSS, total carbohydrates, total sugars, weight loss and sprouting of tuber roots with non significant differences between them.

Therefore, treating sweet potato plants with 1 kg (Nr) + 0.6kg (Pr) + 40kg (N) + 30kg (P_2O_5), can be recommended to improve productivity, tuber root quality, storability as well as reducing the need for minerals and in turn reduced the cost of production and also decreased the environmental pollution.

Key words: Sweet potato, phosphorein, nitrobein, yield, and tuber root quality

INTRODUCTION

Sweet potato *(Ipomoea batatas* L.), is a very important crop in tropical and subtropical regions overall the world. It is a popular vegetable crop in Egypt. The chief use of sweet potato is for human consumption and for starch production.

During last decades, there were realized harmful effects by using enormous amounts of chemicals as mineral fertilizers and pesticides in the agricultural production. It was also noticed that most of the used chemicals accumulate in food chain causing hazardous effects. Parts of these chemical substances also escape to water causing disturbances in biological balance and contaminate the underground water. On the other hand, these chemicals led to depression in the activities of nitrogen fixing bacteria and also in the activities of phosphorus bacteria, which its actively only works at low concentration of these substances (Waksman, 1952).

For these reasons, there was a great attention to use the biofertilizers in the production of sweet potato crop. These modern nutrients (biofertilizer) with the objective of increasing the number of such microorganisms and accelerating certain microbial processes to augment the extent of the availability of nutrients in a form that can be easily assimilated by plants. These microorganisms which are used as a biofertilizer induce simulative effect in plant growth and production by fixing the atmospheric nitrogen in free active state,e.g., rizobacterein and nitrobein. In addition phosphate dissolving bacteria,e.g., phosphorein that mobilizing phosphate and micronutrients. Moreover, nitrobein and rizobacterein secreting growth promoting factors, e.g., cytokinine like substrates and auxin(Saber, 1996 and Awad,1998). So, the use of biofertilizer may be benefit in reducing the high rates of mineral fertilizers and reduce plant and soil contaminations, which may help in increasing sweet potato exportation to the European countries.

Fertilization with mineral and biofertilizers gave taller plants and recorded increased chlorophylls content in leaf tissues (El-Gamal, 1996 on potato; Alphonse *et al*., 2001a on sweet potato), uptake of NPK by different plant parts (Mahendran *et al*., 1996 on potato) and yield (Mahendran and Kumar 1998 on potato; Alphonse *et al*., 2001a on sweet potato).

Fertilization of sweet potato plants with NPK at different rates increased vine length, number of both leaves and branches and leaf area/plant (Alphonse *et al*., 2001a), N.P and K contents in leaf (Etman *et al*., 2002b), yield (Omay and Cosico, 1989; Dayal and Sharma, 1991; Dehura and Swain, 1996) and DM percent, carotene, crude protein, total and reducing sugars and total carbohydrates (Etman *et al*., 2002a). Whereas, fertilization with NPK significantly decreased weight loss in tuber root during storage period (Alphonse *et al*., 2001b).

Therefore, the objective of this work was to reduce the utilization of mineral fertilizers by using biofertilizers in the production of sweet potato under sandy soil conditions.

MATERIALS AND METHODS

Two field experiments were conducted during the two successive summer seasons of 2003 and 2004 at El-Khattara Experimental Farm, Faculty of Agriculture, Zagazig University. Sweet potato plants were grown in sandy soil under drip irrigation system to study the effect of minerals and biofertilizers on the growth, plant chemical composition, yield and its components and tuber root quality, as well as storability of roots of sweet potato plants grown in sandy soil under drip irrigation system.

The physical and chemical properties of the experimental soil and farmyard manure are presented in Tables 1a and 1b.

Table 1a: The physical and chemical properties of the experimental soil.

Properties	2003season	2004season
Physical properties (%)		
Sand	95.72	96.23
Silt	2.15	2.46
Clay	2.13	1.31
Texture	Sandy	Sandy
Chemical properties		
Organic matter (%)	0.06	0.04
pH	8.01	7.96
E.C. (dSm^{-1})	1.99	2.11
Total N (%)	0.12	0.13
available N (ppm)	14.98	13.13
available P (ppm)	13.90	12.30
available K (ppm)	67.00	64.00

Samples of the soil were obtained from 25cm soil surface.

Table 1b. The chemical properties of FYM

Properties	2003 season	2004 season
Organic Matter (%)	13.16	13.60
Total N (%)	0.75	0.78
Total P (%)	0.11	0.12
Total K (%)	0.76	0.65

This experiment included 13 treatments as presented in Table 2

Table 2: Recommended dose of N and P_2O_5 and the amounts of phosphorein and nitrobein (kg/fed.)

(%)			Kg/fed.			
N		P	N	P_2O_5	Nr*	Pr**
Control	100	100	80	60	0.0	0.0
	100	50	80	30	0.0	0.6
	100	25	80	15	0.0	1.2
	50	100	40	60	1.0	0.0
	25	100	20	60	2.0	0.0
	50	50	40	30	1.0	0.6
	25	25	20	15	2.0	1.2
	0	0	0	0	1.0	0.6
	0	0	0	0	2.0	1.2
	0	0	0	0	0.0	0.6
	0	0	0	0	1.0	0.0
	0	0	0	0	0.0	1.2
	0	0	0	0	2.0	0.0

Nr*= Nitrobein, Pr= Phosphorein**

These treatments were arranged in complete randomize block design with four replicates.

All experimental units received equal amounts of farmyard manure (20 m^3/fed.) before transplanting, and received also equal amounts of potassium sulphate (48-52 % K_2O) at a rate of 150 kg/fed. One third of both nitrogen and potassium were added with FYM at soil preparation in the center of rows and covered with sand. The two third amounts of both nitrogen and potassium rates were splitted and applied weekly in eight portions beginning at 20 days from transplanting. Calcium super phosphate was added at soil preparation with FYM.

Ammonium sulphate (20.6 % N), calcium super phosphate (15.5 % P_2O_5) and potassium sulphate (48-52 % K_2O) were applied as sources for nitrogen, phosphorus and potassium, respectively. Biofertilizers (phosphorein and nitrobein) were added at 15 days after transplanting beside the plants and covered with sand, after that the plants were irrigated. The source of phosphorein and nitrobein was the General Organization for Agriculture Equalization Foundation (GOAEF), Ministry of Agriculture, and Egypt.

Sweet potato cv. Mabroka used in this experiment was obtained from El-Kanater El-Khairia Research Station, Agric. Res. Center, Egypt.

The area of experimental unit was 12.6 m^2. It contained three dripper irrigation lines with 6 m in length and 70 cm between each two-dripper irrigation lines. One dripper line was used for measuring the vegetative growth characters, while the other two lines were used for measuring the yield and its components.

Immediately after dipping in Benlate fungicide solution, the selected cuttings (15-20 cm length) were transplanted just beside the dripper lines at 25 cm apart on May 7 during 2003 and 2004 seasons.

The plants were sprayed once at 50 days after transplanting with aqueous solution of micronutrients (40 ppm Fe + 40 ppm Mn + 40 ppm Mg +20 ppm B +10 ppm Zn +20 ppm Cu +20 ppm Mo).

Drip irrigation system was used as a modified method of irrigation. The drippers were with discharge of 2 liter/h. at 1 bar. The normal agricultural treatments (pest control and weed control) of growing sweet potato crop were practiced.

Data Recorded

1. Plant Growth

A random sample of three plants from every experimental unit was taken at 120 days after transplanting in the two seasons for measuring vine length, number of branches/ plant, number of leaves/plant, and number of tuber roots /plant. The different parts of sweet potato plant, i.e., branches and leaves, were dried at 70°C till a constant weight to determine the dry weight of branches, leaves and whole plant.

2. Leaf pigments: A random sample from the fourth upper leaf, recently expanded leaf, on the main stem from every experimental unit was taken at 120 days after transplanting in the two seasons to determine chlorophyll a and b, as well as carotenoides according to the method described by Wettestein (1957).

3. Nitrogen, phosphorus and potassium content: The dry weight of tuber roots, branches and leaves at 120 days after transplanting, in the second season only, were finely grounded and wet digested using sulphoric and perchloric acids (3:1). N, P and K were determined according to the methods described by Bremner and Mulvaney (1982), Olsen and Sommers (1982), and Jackson (1970), respectively.

4.Yield and its components: At harvesting time (150 days after transplanting), tuber roots of every experimental unit were harvested, counted and weighed, then separated into three grades, i.e., oversized, marketable and culls, according to their sizes, as the specification done by the Ministry of Economy for sweet potato exportation (1963). The following data were recorded: average number of tuber roots/plant, average weight of tuber roots/plant, total weight of oversized tuber roots (root diameter over 6 cm), total weight of marketable tuber roots (root diameter 3-6 cm), total weight of cull tuber roots (root diameter less than 3 cm) and total yield of tuber roots per feddan .

5. Tuber root quality: TSS % was determined in flesh juice of tuber roots by Carle Zeis refractometer, carotene was determined according to the method reported by A.O.A.C. (1970), N, P and K were determined as previously described in the plant chemical composition, total carbohydrates was determined according to the method described by Michel *et al.* (1956), total soluble sugars was determined according to the method described by Forsee (1938) and dry matter was recorded as reported by A.O.A.C. (1970).

6. Storability

At harvesting time, the tuber roots of every experimental unit were cured for one week in a shady place, temperature and relative humidity (R.H.) were recorded and the averages were 29 ± 2 °C and 80-85 % (R.H.). On the 1st of October in both seasons, samples of uniform cured oversized, marketable and culls tuber roots (5 kg) from each experimental unit were packed in palm crates and stored for four months at normal room condition. The averages were 20 ± 2 °C and 60-65 % for both temperature and relative humidity, respectively. A completely randomized design with four replicates was employed.

The following data were recorded after 30, 60, 90 and 120 days of storage:

6.1 Weight loss (%): It was estimated according to the following equation:

$$\text{Weight loss (\%) in tuber roots} = \frac{\text{Initial weight-weight of next sampling dates}}{\text{Initial weight}} \times 100$$

Tuber roots of each experimental unit were weighed at 30-day intervals and the cumulative weight loss percentage was calculated.

6.2 Sprouting (%): It was estimated and expressed as percentage of number of sprouted tuber roots, and the cumulative sprouting percentage was calculated.

Statistical analysis: Statistical analysis was conducted for all collected data of both experiments under study. The analysis of variance was calculated according to Snedecor and Cochran (1980), means separation was done according to LSD at 0.05 level of probability.

RESULTS AND DISCUSSION

1. Plant Growth

Data in Tables 3 and 4 indicate that fertilizing sweet potato with mineral N and P (80 kg N +60 kg P_2O_5/fed.) or with mineral (N+P) combined with nitrobein (Nr) and phosphorein (Pr) at different combinations (80 kg N +30 kg P_2O_5 + 0.6 kg Pr, 80 kg N +15 kg P_2O_5 +1.2 kg Pr, 40 kg N+60 kg P_2O_5 +1 kg Nr, 20 kg N +60 kg P_2O_5 +2 kg Nr and 40 kg N +30 kg P_2O_5 +1 kg Nr+0.6 kg Pr/*fed*) recorded the highest vine length and greatest number of branches, leaves, tuber roots and dry weight of branches, leaves and vine/plant with non differences between them . On the other hand, inoculation of transplants of sweet potato with nitrobein and phosphorein singly gave the lowest values of the abovementioned characters.

It is well known that nitrogen is one of the major and most important essential elements. It's an indispensable elementary constituent of numerous organic compounds of general importance amino acids, protein and nucleic acid, also it is needed in formation of protoplasm and new cells, as well as, its encouragement for cell elongation. Phosphorous is a part of molecular structure of nucleic acids (DNA and RNA), the energy transfer components and phosphoprotein (Gardener *et al*., 1985).

Such effect of the above mentioned treatments could be attributed to the activity of bacteria in the absorption zone of plant roots by improving soil fertility and consequently plant development by N_2 – fixation and due to releasing of certain other nutrients, i.e., Fe, Zn and Mn (Bhande *et.al.,*1997), through the breakdown of organic materials in the soil and change these elements into available forms.

These results agree with those reported by El-Gamal (1996) on potato and Alphonse *et al.* (2001 a) on sweet potato. They concluded that mineral or the combination between mineral and biofertilizers gave the highest values of vegetative growth characters.

2. Leaf pigments

The obtained data in Table 5 indicated that mineral N+P singly or combined with the Nr +Pr at different rates recorded the maximum values of chlorophyll a, b and total (a+b) and total carotenoid concentrations in leaf tissues of sweet potato. In general, 80 kg N +60 kg P_2O_5/ *fed*, 80 kg N+30 kg P_2O_5+0.6 kg Pr/*fed*, 80 kg N+15 kg P_2O_5+1.2 kg Pr or 40 kg N+60 kg P_2O_5+1kg Nr/*fed* were the most favourable and effective combination treatments for increasing the concentration of chl a, chl b, total (a+b) and carotenoids in leaf tissues, while Nr and Pr at different rates singly or in combination without mineral fertilizers recorded the minimum values of the studied photosynthetic pigments.

The favorable effect of nitrogen on photosynthetic pigments might be due to that nitrogen is a constituent of chlorophyll molecule. Moreover, nitrogen is the main constituent of all the amino acids and hence of protein and lipids as glactolipids, acting as a structural components of chloroplasts, correspondingly, or enhancement of protein synthesis and chloroplasts (Marschner, 1995).

The obtained results in agreement with those reported by El-Gamal (1996), who found that the combination between N and biofertilizer Halex increased chlorophyll contents in leaf tissues of potato plants.

T3

T4

t5

3. N, P and K uptake

Data in Table 6 indicate that fertilization of sweet potato with mineral N+P at 80 kg N +60 kg P_2O_5 kg/*fed*, 80 kg N +30 kg P_2O_5 +0.6 kg Pr/*fed*, 80 kg N+15 kg P_2O_5 +1.2 kg Pr/fed., 40 kg N +60 kg P_2O_5 +1 kg Nr or 20 kg N +60 kg P_2O_5 +2 kg Nr/*fed* gave the highest N,P and K uptake and total uptake by plant, while biofertilizers Nr and Pr at different rates singly or in combination without mineral fertilizers gave the lowest values of N,P and K uptake and total uptake. Ayoub (2005), under sandy soil conditions, using fertigation with 60 kg N + 60 kg K_2O/*fed* recorded the highest values of N, P and K and their total uptake in different plant parts; i.e., branches leaves and tuber roots as well as total uptake/plant, except, for P and K uptake in branches and P uptake in leaves.

These results agree with those reported by Mahendran *et al*. (1996), on potato, they found that mineral and biofertilizers increased uptake of NPK by different plant parts. Etman *et al*. (2002b) found also that mineral NPK increased NP and K contents in leaf tissues of sweet potato.

4. Yield and Its Components

The obtained data in Tables 7 and 8 reveal that the combination between mineral and biofertilizers at different rates had no significant effect on number of tuber roots/ plant in both seasons. While it did significantly increase average tuber root weight, yield / plant, yield of oversized, marketable, culls and total yield/ fed in both seasons, except tuber root culls in the second season. Fertilization of sweet potato with N+P at 80 kg +60 kg/*fed* or the combination between N+P and Nr +Pr at different rates, i.e., (80 N +60 P_2O_5, 80 N+30 P_2O_5+0.6 Pr, 80 N+15 P_2O_5+1.2 Pr, 40 N+60 P_2O_5+1Nr and 40 N + 30 P_2O_5 + 1 Nr + 0.6 Pr)kg / *fed* , recorded the maximum values of average tuber root weight, yield / plant and yield of oversized, marketable and total yield, with no significant differences among them. Whereas, Nr and Pr at different rates without mineral fertilizers gave the lowest values of yield and its components.

These results may be due to that N+P alone or in combination with Nr + Pr at different rates had a significant positive effect on plant growth (Tables 3 and 4), and N, P and K concentrations in branches and leaves (Table 6).

These results are in a good line with those reported by Omay and Cosico (1989), Dayal and Sharma (1991) and Dehura and Swain (1996), who found that N or N+P at different rates produced the highest total yield/ *fed*. Also El-Gamal (1996), Mahendran and Kumar (1998) on potato, and Alphonse *et al*. (2001a) on sweet potato found that the combination between mineral and biofertilizers at different rates recorded the maximum values of total yield.

5. Tuber root quality

As presented in Table 9, mineral N+P only or in combination with nitrobein and phosphorein at different rates, generally, recorded the maximum values of tuber root quality, i.e., carotene, TSS, N, and K contents, compared with nitrobein and phosphorein singly or their combination at different rates without mineral fertilizers. Whereas, percent of dry matter and P were not affected. On the other hand, total carbohydrate and sugars did not show clear trends.

T6

t7

t8

T9

These results agree with those reported by Etman *et al*. (2002a) regarding the effect of mineral fertilizer on tuber root quality.

6. Storability

6.1. Weight loss percentage

Data in Tables 10 and 11 indicate that fertilization of sweet potato with mineral N and P at 80 kg N + 60 kg P_2O_5/fed. or with mineral (N+P) combined with nitrobein (Nr) or phosphorein (Pr) at different combinations recorded, generally, the highest weight loss percentage in oversized , marketable and cull tuber roots of sweet potato during storage period. On the other hand, inoculation of transplants of sweet potato with Nr and Pr singly without mineral fertilizers gave the lowest values of the weight loss percentage of marketable and culls tuber roots during storage period with non significant differences between them. In general, mineral N+P at 80 kg N + 60 kg P_2O_5, 80 kg N + 30 kg P_2O_5 + 0.6 kg Pr /fed. , 80 kg N + 15 kg P_2O_5 +1.2 kg Pr or 40 kg N + 60 kg P_2O_5 +1 kg Nr recorded the maximum values of weight loss percentage.

These results might be attributed to the increase in weight of oversized and marketable tuber roots and this, in turn increased water loss through evaporation and dry matter loss by high respiration, thereby affected weight loss of tuber roots during storage.

The obtained results contradicted with those reported by Alphonse *et al.* (2001b) on sweet potato, who found that applying half dose NPK (50+100+50 kg/*fed*) significantly decreased weight loss percentage in tuber roots during storage period.

6.2 Sprouting percentage

Data in Tables 12 and 13 indicate that sprouting started at 30 days from the beginning of storage in both seasons for oversized and marketable tuber roots, whereas, sprouting in culls was noticed after sixty days in storage. The sprouting percentage in cull tuber roots was the lowest comparing to oversized and marketable tuber roots.

Fertilization of sweet potato with mineral N and P at 80 kg N + 60 kg P_2O_5/fed. , 80 kg N + 30 kg P_2O_5 + 0.6 kg Pr/fed., 80 kg N + 15 kg P_2O_5 +1.2 kg Pr or 40 kg N + 60 kg P_2O_5 +1 kg Nr recorded the highest sprouting percentage in oversized, marketable and cull tuber roots during all storage period, while inoculation of transplants with Nr and Pr singly without mineral fertilizers gave the lowest values of this parameter in oversized, marketable and cull tuber roots during storage.

These results agree with those reported by Al-Easily (2002) on sweet potato. Who found that the combination between 90 kg N +150 kg K_2O recorded the highest value of sprouting during storage?

From the results of this study, it could be concluded that sweet potato plants inoculations with 1 kg (Nr) + 0.6kg (Pr) + 40kg (N) + 30kg (P_2O_5), could be a recommended treatment for improving productivity and storability. Therefore, this biofertilizer application reduced the need for mineral fertilizer by about 50 %, which in turn reduced the production cost and also decreased the environmental pollution.

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تأثير التسميد الكيماوى والحيوى على النمو ، المحصول ، وجودة الجذور المتدرنة والقدرة التخزينية لنباتات البطاطا النامية فى الأرض الرملية

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2. معهد بحوث البساتين - مركز البحوث الزراعية- مصر

أجريت تجربتان حقليتان خلال موسمي صيف 2003 و2004 فى مزرعة التجارب الزراعية بالخطارة التابعة لكلية الزراعة – جامعة الزقازيق ، بهدف دراسة تأثير مختلف التوليفات بين التسميد النيتروجيني والفوسفاتي المعدنى والحيوى على صفات النمو والمحتوى المعدني، والمحصول ومكوناته ، وجودة الجذور المخزنة ، والقدرة التخزينية لجذور البطاطا تحت نظام الرى بالتنقيط.

أدى تسميد نباتات البطاطا بالأسمدة المعدنية النيتروجينية والفوسفاتية بمعدل 80+60 كجم/فدان (ن +فو$_{2}$أ$_{5}$) أو بالتسميد المعدنى NP مع الحيوى بمعدل 80+30 +0.6 كجم فوسفورين / فدان أو 80+15+1.2 كجم فوسفورين أو 40+60+1 كجم نيتروبين او 20+60+2 كجم نتروبين / فدان او 40+30+1 كجم نتروبين +0.6 كجم فوسفورين/ فدان و 20+15+2 كجم نتروبين +1.2 كجم فوسفورين/ فدان الى زيادة معنوية فى صفات النمو (طول العرش، وعدد كل من الأفرع والأوراق على النبات ، الوزن الجاف لاجزاء النبات المختلفة، عدد الجذور المتدرنة على النبات والمحصول الكلى مقارنة بالاسمدة الحيوية فقط.

وعموما فان تسميد البطاط ابمعدل 80 كجم ن+ 60 كجم فو$_{2}$أ$_{5}$ / للفدان او عمل توليفات مع النتروبين والفوسفورين بمعدلات مختلفة يؤدى الى الحصول على اعلى قيم لمتوسط وزن الجذور الدرنية ، محصول النبات، محصول الدرنات الكبيرة الحجم والقابلة للتسويق وكذلك المحصول الكلى للفدان ، بينما اعطى التسميد بالنتروبين والفوسفورين بمفردهما اقل القيم للمحصول ومكوناته.

وقد اظهرت النتائج ان معاملة البطاطا بالمخصبات الحيوية بدون التسميد المعدني ،اعطى جذور درنية ذات جودة وقدرة تخزينية عالية من حيث النسبة المئوية لمحتوى المواد الكلية الصلبة الذائبة،الكربوهيدرات والسكريات الكلية، الفقد فى الوزن والتزريع بدون فروق معنوية بينهم.

يمكن التوصية بتسميد البطاطا بـ 40 ن +30 فو$_{2}$أ$_{5}$ + ا نتروبين +0.6 فوسفورين كجم/ للفدان لتحسين الانتاجية ،الجودة والقدرة التخزينية للجذور الدرنية ، مما يقلل الحاجة لاستعمال الاسمدة المعدنية ، وبالتالى تخفيض تكاليف الانتاج وتقليل التلوث البيئى .

Table 3: Effect of mineral and biofertilizers on plant growth characters of sweet potato plants grown in sandy soil in 2003 season

N	P_2O_5	Nr*	Pr**	Morphological characters				Dry weight (gm/organ)		
				Vine length (cm)	Number/plant			Branches	Leaves	Vine
(Kg/*fed*)					Branches	Leaves	Tuber roots			
80	**60**	**0**	**0.0**	158.3	14.50	145.2	4.35	116.40	103.90	220.30
80	**30**	**0**	**0.6**	148.5	13.50	137.3	4.33	91.01	100.00	191.01
80	**15**	**0**	**1.2**	161.7	10.50	138.8	3.83	92.35	90.44	182.79
40	**60**	**1**	**0.0**	139.2	11.17	143.3	3.66	127.60	86.33	213.93
20	**60**	**2**	**0.0**	166.3	14.00	133.0	3.16	84.25	84.31	168.56
40	**30**	**1**	**0.6**	129.2	12.33	140.7	3.00	97.14	94.10	191.24
20	**15**	**2**	**1.2**	173.3	9.66	133.5	3.83	70.11	92.74	162.85
0	**0**	**1**	**0.6**	121.7	9.66	121.7	3.16	56.79	67.30	124.09
0	**0**	**2**	**1.2**	121.0	9.16	139.3	2.66	64.84	62.58	127.42
0	**0**	**0**	**0.6**	106.2	9.16	106.2	1.66	50.46	35.78	86.24
0	**0**	**1**	**0.0**	112.0	10.0	131.7	1.50	55.37	56.22	111.59
0	**0**	**0**	**1.2**	105.0	8.00	107.7	1.83	40.99	34.21	75.20
0	**0**	**2**	**0.0**	119.0	9.33	113.8	2.16	52.75	40.91	93.66
L.S.D. at 0.05 level				**36.71**	**3.72**	**25.40**	**1.38**	**41.71**	**20.21**	**46.01**

Table 4: Effect of mineral and biofertilizers on plant growth characters of sweet potato plants grown in sandy soil in 2004 season

N	P_2O_5	Nr*	Pr**	Morphological characters				Dry weight (gm/organ)		
				Vine length (cm)	Number/plant			Branches	Leaves	Vine
(Kg/*fed*)					Branches	Leaves	Tuber roots			
80	**60**	**0**	**0.0**	122.8	17.83	228.5	4.00	135.10	97.87	232.97
80	**30**	**0**	**0.6**	124.0	16.33	234.3	4.16	129.90	89.63	219.53
80	**15**	**0**	**1.2**	120.2	11.33	189.7	2.83	106.80	80.14	186.94
40	**60**	**1**	**0.0**	112.2	14.00	210.5	3.16	127.60	74.17	201.77
20	**60**	**2**	**0.0**	95.67	9.66	174.5	.3.50	102.80	72.91	175.71
40	**30**	**1**	**0.6**	107.7	14.67	251.7	3.16	119.90	69.26	189.16
20	**15**	**2**	**1.2**	102.5	9.66	180.5	3.33	115.60	59.48	175.08
0	**0**	**1**	**0.6**	80.00	10.17	208.2	2.83	90.75	53.30	144.05
0	**0**	**2**	**1.2**	92.17	10.67	209.8	3.00	98.70	52.34	151.04
0	**0**	**0**	**0.6**	79.50	9.66	119.2	2.16	90.70	49.58	140.28
0	**0**	**1**	**0.0**	96.67	10.33	159.2	2.16	100.60	48.49	149.09
0	**0**	**0**	**1.2**	85.67	8.00	123.7	2.16	87.14	45.84	132.98
0	**0**	**2**	**0.0**	81.00	10.67	143.0	3.16	98.48	50.16	148.64
L.S.D. at 0.05 level				**24.59**	**3.49**	**40.16**	**0.94**	**26.80**	**20.01**	**34.41**

Nr* = Nitrobein   Pr** =Phosphorein

Table 5: Effect of mineral and biofertilizers on the leaf pigments (mg/gm dry weight) of sweet potato plants grown in sandy soil in 2003 and 2004 seasons

N	P_2O_5	Nr*	Pr**	2003season				2004season			
				Chlorophyll			Carotenoids	Chlorophyll			Carotenoids
(Kg/feddan)				a	b	Total (a+b)		a	b	Total (a+b)	
80	60	0	0.0	3.15	2.03	5.18	3.79	3.30	1.05	4.35	1.60
80	30	0	0.6	3.06	2.00	5.06	3.21	3.23	1.11	4.34	1.66
80	15	0	1.2	3.06	2.08	5.14	3.06	2.90	1.08	3.98	1.68
40	60	1	0.0	2.55	2.03	4.58	2.94	2.75	1.20	3.95	1.41
20	60	2	0.0	2.32	1.99	4.31	1.94	2.69	1.00	3.69	1.24
40	30	1	0.6	2.74	1.89	4.63	2.25	2.91	0.95	3.86	1.13
20	15	2	1.2	2.63	1.80	4.43	2.13	2.26	1.12	3.38	1.19
0	0	1	0.6	2.28	1.76	4.04	2.53	2.26	0.99	3.25	1.03
0	0	2	1.2	2.40	1.47	3.87	2.29	2.19	0.94	3.13	1.01
0	0	0	0.6	2.23	1.46	3.69	2.28	2.15	0.91	3.06	1.09
0	0	1	0.0	2.19	2.84	4.03	2.28	2.26	0.89	3.15	1.08
0	0	0	1.2	2.23	1.80	4.03	2.19	2.40	0.92	3.32	1.04
0	0	2	0.0	2.24	1.94	4.18	2.23	2.09	0.92	3.01	1.16
L.S.D. at 0.05 level				**0.62**	**0.34**	**1.05**	**0.66**	**0.52**	**0.19**	**0.76**	**0.58**

Nr* = Nitrobein   Pr =Phosphorein.**

Table 6: Effect of mineral and biofertilizers on uptake and total uptake of sweet potato plants grown in sandy soil in 2004 season

N	P_2O_5	Nr*	Pr**	Uptake (mg/organ) Stems N	Stems P	Stems K	Leaves N	Leaves P	Leaves K	Total uptake(mg by plant) N	P	K
(Kg/*fed*)												
80	60	0	0.0	3580.15	405.30	2688.49	4306.28	414.96	3259.07	7886.43	820.26	5947.56
80	30	0	0.6	3559.26	388.40	2507.07	3880.97	351.34	3065.34	7440.23	739.75	5572.41
80	15	0	1.2	2680.68	278.74	2050.56	3397.93	321.36	2644.62	6078.61	600.10	4695.18
40	60	1	0.0	2934.80	331.76	2449.92	3048.38	300.38	2380.85	5983.18	632.14	4830.77
20	60	2	0.0	2436.36	277.56	1901.80	2850.78	306.22	2515.39	5287.14	583.78	4417.19
40	30	1	0.6	2925.56	323.73	2565.86	2908.92	280.50	2618.02	5834.48	604.23	5183.88
20	15	2	1.2	2716.60	242.76	1942.08	2450.57	221.86	2266.18	5167.17	464.62	4208.26
0	0	1	0.6	2014.65	214.17	1488.30	1897.48	196.67	1961.44	3912.13	410.84	3449.74
0	0	2	1.2	2260.23	197.40	1431.15	1816.19	157.54	1826.66	4076.42	354.94	3257.81
0	0	0	0.6	1714.23	201.35	1297.01	1809.67	153.69	1794.79	3523.90	355.05	3091.80
0	0	1	0.0	2022.06	188.12	1438.58	1779.58	153.71	1774.73	3801.64	341.83	3213.31
0	0	0	1.2	1551.09	155.98	1402.95	1618.15	146.22	1581.48	3169.24	302.21	2984.43
0	0	2	0.0	2097.62	174.30	1812.03	1790.71	151.98	1891.03	3888.33	326.29	3703.06
L.S.D. at 0.05 level				541.60	146.70	805.40	1003.00	148.80	769.30	1047.00	251.10	632.30

Nr* = Nitrobein   Pr** =Phosphorein.

Table 7: Effect of mineral and biofertilizers on yield and its components of sweet potato plants grown in sandy soil in 2003 season

N	P_2O_5	Nr*	Pr**	No. of tuber roots /plant	Average tuber root weight (gm)	Yield / plant (kg)	Yield of tuber roots (ton /*fed*)			
(Kg/*fed*)							Oversized	Marketable	Culls	Total
80	**60**	**0**	**0.0**	2.71	0.225	0.690	2.992	9.866	0.300	13.158
80	**30**	**0**	**0.6**	2.62	0.263	0.690	2.920	9.716	0.700	13.336
80	**15**	**0**	**1.2**	2.66	0.241	0.642	2.834	9.300	0.266	12.400
40	**60**	**1**	**0.0**	2.39	0.256	0.613	3.000	8.666	0.400	12.066
20	**60**	**2**	**0.0**	2.44	0.244	0.596	3.966	7.400	0.732	12.098
40	**30**	**1**	**0.6**	2.64	0.225	0.592	2.266	9.200	0.400	11.866
20	**15**	**2**	**1.2**	3.43	0.225	0.542	3.134	6.178	0.766	11.078
0	**0**	**1**	**0.6**	2.73	0.158	0.432	3.434	4.466	0.580	8.400
0	**0**	**2**	**1.2**	3.11	0.144	0.449	3.526	4.446	0.680	8.652
0	**0**	**0**	**0.6**	2.94	0.140	0.415	2.000	5.434	0.566	8.000
0	**0**	**1**	**0.0**	2.82	0.136	0.384	2.400	4.000	0.932	7.332
0	**0**	**0**	**1.2**	2.86	0.132	0.378	2.086	4.466	0.632	7.184
0	**0**	**2**	**0.0**	2.63	0.147	0.387	2.034	4.700	0.632	7.366
L.S.D. at 0.05 level				**N.S.**	**0.106**	**0.106**	**1.344**	**1.730**	**0.384**	**2.126**

Nr* = Nitrobein Pr =Phosphorein.**

Table 8: Effect of mineral and biofertilizers on yield and its components of sweet potato plants grown in sandy soil in 2004 season

N	P_2O_5	Nr*	Pr**	No. of tuber roots /plant	Average tuber root weight (gm)	Yield / plant (kg)	Yield of tuber roots (ton /*fed*)			
(Kg/*fed*)							Oversized	Marketable	Culls	Total
80	60	0	0.0	2.26	0.353	0.798	3.266	10.754	1.566	15.577
80	30	0	0.6	2.38	0.349	0.826	4.826	9.954	1.526	16.306
80	15	0	1.2	2.42	0.339	0.822	5.849	8.664	1.172	15.980
40	60	1	0.0	2.33	0.320	0.746	5.680	7.660	1.000	14.430
20	60	2	0.0	2.29	0.335	0.761	5.154	7.700	1.280	14.134
40	30	1	0.6	2.04	0.338	0.692	5.100	6.940	1.700	13.740
20	15	2	1.2	2.17	0.298	0.648	4.846	6.320	1.700	12.866
0	0	1	0.6	2.5	0.195	0.488	3.020	5.546	0.946	9.512
0	0	2	1.2	2.26	0.217	0.469	2.674	5.006	1.446	9.126
0	0	0	0.6	2.11	0.218	0.461	2.734	5.054	1.235	9.029
0	0	1	0.0	2.30	0.215	0.495	2.546	5.014	1.926	9.786
0	0	0	1.2	1.89	0.221	0.418	1.486	4.924	1.732	8.142
0	0	2	0.0	2.19	0.194	0.425	1.434	5.136	1.734	8.343
L.S.D. at 0.05 level				N.S.	0.075	0.238	1.680	2.036	N.S.	2.526

Nr* = Nitrobein   Pr** =Phosphorein.

Table 9: Effect of mineral and biofertilizers on the tuber root quality at harvest date of sweet potato plants grown in sandy soil in 2004 season.

N	P_2O_5	Nr*	Pr**	Tuber root quality							
				Carotene (mg/gm FW)	TSS (%)	Dry matter (%)	Total (%)		Mineral content (%)		
(Kg/*fed*)							Carbohydrates	sugars	N	P	K
80	60	0	0.0	2.41	9.83	18.73	82.53	13.81	1.94	0.251	1.90
80	30	0	0.6	2.40	10.00	18.85	83.73	13.47	1.97	0.225	2.01
80	15	0	1.2	2.51	10.33	18.74	80.40	14.37	1.97	0.210	1.68
40	60	1	0.0	1.86	9.83	17.88	82.53	13.73	1.92	0.248	2.41
20	60	2	0.0	1.74	9.16	16.67	83.80	14.54	1.88	0.250	2.55
40	30	1	0.6	1.73	10.00	17.26	80.80	13.77	2.03	0.244	1.94
20	15	2	1.2	1.93	8.33	17.84	84.73	13.46	1.72	0.230	2.33
0	0	1	0.6	1.89	9.66	16.96	84.80	14.16	1.51	0.215	1.95
0	0	2	1.2	2.06	10.33	17.23	83.80	14.18	1.59	0.204	1.62
0	0	0	0.6	1.93	9.16	17.30	84.07	14.52	1.45	0.210	1.78
0	0	1	0.0	1.72	9.33	17.94	84.60	13.93	1.69	0.222	2.12
0	0	0	1.2	1.70	9.83	17.59	80.67	14.14	1.43	0.206	2.15
0	0	2	0.0	1.94	8.33	17.43	84.60	13.48	1.59	0.222	2.29
L.S.D. at 0.05 level				0.36	1.02	N.S.	2.55	0.65	0.38	N.S.	0.44

Nr* = Nitrobein   Pr** =Phospho rein

Table 10: Effect of mineral and biofertilizers on weight loss (%) in tuber roots of sweet potato during storage period in 2003 season

N	P_2O_5	Nr*	Pr**	Weight loss (%)											
				Oversized				Marketable				Culls			
				Days in storage											
(Kg/*fed*)				30	60	90	120	30	60	90	120	30	60	90	120
80	60	0	0.0	28.52	44.52	55.90	67.05	24.26	38.52	48.75	50.68	18.33	25.56	36.67	47.78
80	30	0	0.6	38.17	49.30	57.61	67.69	23.30	38.80	47.20	53.78	22.42	30.33	38.83	47.17
80	15	0	1.2	42.40	52.07	55.61	60.96	2305	35.39	44.29	55.56	17.78	23.11	38.11	40.00
40	60	1	0.0	35.35	53.84	61.43	64.78	20.74	37.38	41.83	56.97	15.67	23.22	38.33	39.22
20	60	2	0.0	22.53	27.62	34.17	38.43	2308	33.78	40.51	52.94	15.25	21.13	28.38	37.98
40	30	1	0.6	31.83	39.18	45.07	50.05	22.37	31.31	40.28	56.95	12.94	23.97	32.38	40.12
20	15	2	1.2	20.26	39.19	43.74	49.91	22.41	36.99	45.02	56.06	20.83	36.94	44.35	48.83
0	0	1	0.6	15.56	21.19	27.34	31.19	13.49	25.27	30.42	44.74	13.83	22.50	31.83	34.00
0	0	2	1.2	15.88	20.38	22.93	27.90	14.84	26.50	34.32	48.94	12.44	21.06	32.56	40.65
0	0	0	0.6	21.41	17.01	22.20	26.46	13.94	25.78	33.55	47.03	14.88	19.40	33.98	33.17
0	0	1	0.0	13.75	18.23	23.28	28.05	11.65	24.49	29.97	39.98	11.83	15.50	22.56	28.11
0	0	0	1.2	13.83	18.02	24.48	29.35	13.37	25.51	29.47	38.53	12.68	19.24	29.55	29.05
0	0	2	0.0	16.49	22.90	25.42	30.01	10.98	18.90	30.17	43.72	12.08	16.67	24.58	27.33
L.S.D. at 0.05 level				**10.05**	**12.80**	**12.58**	**12.05**	**5.57**	**9.51**	**10.32**	**15.46**	**8.04**	**9.49**	**11.07**	**9.41**

Nr* = Nitrobein   Pr =Phosphorein.**

Table 11: Effect of mineral and biofertilizers on weight loss (%) in tuber roots of sweet potato during storage period in 2004 season

N	P_2O_5	Nr*	Pr**	Weight loss (%)											
				Oversized				Marketable				Culls			
				Days in storage											
(Kg/*fed*)				30	60	90	120	30	60	90	120	30	60	90	120
80	60	0	0.0	24.26	38.52	48.75	50.68	18.24	32.03	42.09	54.43	16.92	33.93	40.00	50.96
80	30	0	0.6	23.30	38.80	47.20	53.78	20.73	27.98	36.99	45.90	15.73	25.91	38.95	52.87
80	15	0	1.2	23.05	35.39	44.29	55.56	20.53	29.59	37.15	47.82	19.23	31.79	46.40	49.46
40	60	1	0.0	20.74	37.38	41.83	56.97	23.35	32.54	39.65	50.53	17.01	28.69	39.73	48.16
20	60	2	0.0	23.08	33.78	40.51	52.94	18.02	29.41	38.81	45.95	18.95	27.80	38.52	47.72
40	30	1	0.6	22.37	32.31	40.28	56.95	17.75	24.74	37.32	46.25	18.58	24.18	33.03	40.90
20	15	2	1.2	22.41	36.99	45.02	56.06	24.22	30.50	38.48	49.04	16.01	26.88	35.72	43.50
0	0	1	0.6	13.49	25.27	30.42	44.74	11.66	19.67	33.67	37.87	13.58	23.01	32.58	38.46
0	0	2	1.2	14.84	26.50	34.32	48.94	17.33	22.32	34.04	40.02	17.20	23.60	26.67	34.92
0	0	0	0.6	13.94	25.78	33.55	47.03	13.56	21.40	27.50	39.61	15.28	25.83	31.22	37.00
0	0	1	0.0	11.65	24.49	29.97	39.98	13.93	22.53	32.81	40.01	15.97	16.82	24.83	28.11
0	0	0	1.2	13.37	25.51	29.47	38.53	14.16	23.07	31.27	35.72	15.74	22.71	26.51	33.21
0	0	2	0.0	10.98	18.90	30.17	43.72	20.47	21.62	25.00	35.26	10.18	15.73	23.09	26.59
L.S.D. at 0.0				5.57	9.51	10.32	15.46	12.12	N.S.	14.52	16.58	8.28	11.00	11.04	9.13

Nr* = Nitrobein Pr =Phosphorein.**

Table 12: Effect of combination with mineral and biofertilizers on sprouting (%) in tuber roots of sweet potato during storage period in 2003 season

N	P_2O_5	Nr*	Pr**	Sprouting (%)											
				Oversized				Marketable				Culls			
				Days in storage											
(Kg/feddan)				30	60	90	120	30	60	90	120	30	60	90	120
80	60	0	0.0	16.67	25.00	41.67	50.00	6.66	26.67	33.33	46.67	0.00	13.33	13.33	13.33
80	30	0	0.6	20.00	26.67	33.33	53.33	10.32	20.63	38.73	38.73	0.00	15.76	15.76	15.76
80	15	0	1.2	8.33	13.89	32.78	46.67	8.33	16.67	27.78	38.89	0.00	4.16	4.16	8.33
40	60	1	0.0	15.00	21.67	36.67	46.67	16.67	16.67	30.00	53.33	0.00	4.16	4.16	8.33
20	60	2	0.0	19.44	19.44	27.78	33.33	8.33	8.33	17.86	47.62	0.00	5.55	5.55	5.55
40	30	1	0.6	8.33	8.33	16.67	30.00	11.43	11.43	16.10	29.52	0.00	0.00	0.00	0.00
20	15	2	1.2	0.00	6.66	17.78	28.11	0.00	0.00	16.10	26.51	0.00	6.66	6.66	6.66
0	0	1	0.6	0.00	8.33	8.33	8.33	0.00	0.00	10.32	17.50	0.00	4.44	4.44	4.44
0	0	2	1.2	0.00	8.33	16.67	30.33	4.16	8.33	13.89	13.89	0.00	1.58	1.58	1.58
0	0	0	0.6	0.00	0.00	6.66	6.66	0.00	0.00	10.83	10.83	0.00	0.00	0.00	0.00
0	0	1	0.0	0.00	0.00	0.00	8.33	5.55	5.55	10.32	10.32	0.00	5.59	5.59	8.37
0	0	0	1.2	0.00	0.00	7.66	6.66	0.00	0.00	13.10	13.10	0.00	2.56	2.56	2.56
0	0	2	0.0	0.00	0.00	0.00	6.66	0.00	0.00	4.66	8.92	0.00	0.00	4.16	6.25
L.S.D. at 0				14.43	21.91	22.38	20.66	N.S.	17.82	16.80	19.03	---	11.90	12.19	14.52

Nr* = Nitrobein   Pr =Phosphorein.**

Table 13: Effect of mineral and biofertilizers on sprouting (%) in tuber roots of sweet potato during storage period in 2004 season

N	P_2O_5	Nr*	Pr**	Sprouting (%)											
				Oversized				Marketable				Culls			
				Days in storage											
(Kg/*fed*)				30	60	90	120	30	60	90	120	30	60	90	120
80	60	0	0.0	26.11	34.44	45.56	58.89	0.00	38.89	53.22	61.11	0.00	13.89	20.56	20.56
80	30	0	0.6	13.33	13.33	46.67	60.00	0.00	40.12	56.67	57.62	0.00	19.76	25.00	33.93
80	15	0	1.2	12.17	28.04	28.04	52.38	0.00	35.95	35.95	53.21	0.00	10.37	17.04	17.04
40	60	1	0.0	4.76	16.19	16.19	48.49	0.00	36.67	40.00	53.33	0.00	4.16	10.83	18.92
20	60	2	0.0	5.55	10.32	10.32	15.08	0.00	24.52	31.19	40.12	0.00	7.40	7.40	7.40
40	30	1	0.6	0.00	6.66	6.66	13.33	0.00	24.07	24.07	36.11	0.00	0.00	8.70	8.70
20	15	2	1.2	11.43	11.43	11.43	24.76	0.00	19.44	24.21	26.11	0.00	8.33	8.33	8.33
0	0	1	0.6	4.16	4.16	4.16	8.33	0.00	12.04	21.30	23.24	0.00	5.00	5.00	8.33
0	0	2	1.2	0.00	0.00	0.00	8.33	0.00	13.89	13.89	25.00	0.00	4.76	4.76	9.52
0	0	0	0.6	0.00	4.76	4.76	13.10	0.00	8.92	14.52	23.14	0.00	0.00	0.00	0.00
0	0	1	0.0	0.00	0.00	0.00	6.66	0.00	5.55	11.11	11.11	0.00	3.70	7.40	15.87
0	0	0	1.2	4.76	4.76	4.76	10.32	0.00	7.40	18.98	18.98	0.00	4.38	9.72	13.06
0	0	2	0.0	4.76	4.76	4.76	10.32	0.00	4.16	4.16	8.92	0.00	4.33	7.50	7.50
LSD. at 0.(				**9.54**	**15.20**	**15.20**	**18.29**	---	**14.32**	**14.86**	**17.04**	----	**16.31**	**18.43**	**14.99**

Nr* = Nitrobein Pr =Phosphorein**