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Growth and yield response of sweet potato (*Ipomoea batatas* L.) cv. NDSP-65 to different integrated organic sources

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Abstract
A field experiment was conducted in the *rabi* season at Department of Vegetable Science, N.D.U.A. & T., Faizabad (U.P.) during 2015-16, to find out the suitable doses of organic manures for sustainable production of Sweet Potato (*Ipomoea batatas* L.). The total of eleven doses of organic manures along with different combinations was evaluated by using randomized block design. Earliest initiation of buds (7.93 days) was observed in T_1 (FYM @ 20 t/ha). T_{11} {recommended dose of FYM (10 t/ha) and NPK (50:25:50)} was identified as a good combination for number of leaves per plant, leaf area, foliage weight per plant, number of vine per plant, inter nodal length, number of tuber plant, fresh weight of tuber per plant, length of tubers and yield per hectare. However for all organic sources, treatment T_7 {FYM @ 10 t / ha + Poultry manure @ 2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} could be used for improving growth and yield along with related traits of sweet potato. Hence, it is suggested that these remunerative treatment of organic doses help in successful crop production of sweet potato.

Keywords: NDSP-65, organic manures, growth, tuber yield

Introduction
It can also improve the nutrients and is absolutely harmless to plants. Sweet potato [*Ipomoea batatas* (L.) Lam] is important root crops, belongs to family convolvulaceae, considered to be widely grown in tropical and sub-tropical regions of the world (Onunka *et al.*, 2012) [22]. In India, sweet potato area, production and productivity were 0.11 million hectares, 1.45 million tonnes and 13.06 tonnes per hectare, respectively (Anonymous, 2015) [6]. The sweet starchy edible tuberous roots have economic values that contain about 27% carbohydrate and high concentration of Vitamin A, Vitamin C, calcium and iron. Sometimes, young leaves and shoots are also eaten as greens (Abidin, 2004) [2]. It is a rich source of carotene, ascorbic acid, thiamine, riboflavin, protein and energy. Because of the high nutritional and economic value, it is necessary to improve yield and its related traits that can be achieve through balance availability of all the nutrients in the crop. No single source is capable to supply the required quantity of plant nutrients. Due to continuous application of inorganic fertilizers in the soil, had negative effect on soil and also productivity of the crop (Lal and Kang, 1982) [14].

There is large number of organic sources such as farm yard manure, town compost, horse manure, sewage sludge, press mud, goat and sheep manure, cattle manure, vermi-compost etc. These could be used to reduce the total cost of cultivation and to supplement the essential nutrients for better growth and development of the plants. In recent past research, it is found that the root yield of sweet potato increases with application of inorganic fertilizers but adversely affects the quality (Nedunchezhiyan and Srinivasulu Reddy, 2002) [17]. However, optimum amount of nitrogen particularly organically increases quality (Nedunchezhiyan *et al*., 2003) [18].

Bio-fertilizers is one of the most important organic source, contain beneficial viable-organisms which have ability to mobilize nutritionally important elements from non-usable to usable form through biological processes (Oliveira *et al.*, 2010) [21]. *Azospirillum* is known to be a very active nitrogen fixer under laboratory as well as soil condition providing fast growth, better health of the plant and higher yield (Kannan and Ponmurugan, 2010) [12]. The response of organic sources with or without chemical fertilizers on a large number of crops have been reported by several workers (Nedunchezhiyan *et al*., 2010; Sowley *et al.*, 2015; Koodi *et al.*, 2017) [19, 29, 13]. Considering this, the present study was undertaken to find out the suitable organic sources for higher yield of sweet potato with the economic feasibility of the treatments.

Materials and Methods

The experiment was carried out during 2015-2016, at Main Experiment Station, Department of Vegetable Science, N.D.U.A. & T., Faizabad (U.P) India. The experimental site falls under sub-humid, subtropical climate and is located at 26.47^0 N latitude and 82.12^0 E longitudes on an elevation of 113 meters above mean sea level in the Indo-gangetic alluvial plains of eastern Uttar Pradesh. Maximum rainfall in this area is received from mid-June to end of September. The weekly maximum and minimum temperatures during the crop growth period ranged from 36.6 and 20.1 and 25.8 to 5.2, respectively. The total rainfall recorded during the crop period was 15.2 mm.

A well prepared manured nursery having good drainage helps in producing better planting materials. Planting in nursery is done 3 months before ahead of planting in main field. The selected tubers are planted 5-10 cm deep at a spacing of 30 cm in rows, 60 cm a part. The sprouts are often cut after 40-45 days and planted in secondary planted nursery for further growth. The vine cutting, 20-30 cm in length, the cuttings are made and planted in the field, with a spacing of 60 cm x 30 cm. All the recommended agronomic package of practices and plant protection measures were followed to raise a good crop. The crop was harvested on 4th and 5th February during the year 2015-2016.

The recommended dose of NPK was 50:25:50 kg/ha and 25:12.5:25 kg/ha. Nitrogen fertilizers were applied as per treatments under study at the last ploughing, the whole quantity of organic manure, vermicompost and biofertilizer was incorporated in the soil as per treatment under study. The different treatments are given in table 1 with the details of doses.

Observations recorded on five randomly selected plants from each genotype in each replication for growth and yield along with related characters *viz.*, days to initiation of buds, number of leaves per plant, leaf area, foliage weight per plant, number of vine per plant, inter nodal length, tuber weight, number of tubers per plant, fresh weight of tuber per plant, length of tubers, diameter of tubers and yield per hectare. The collected data were averaged to get mean values of the respective characters that has been affected by various treatments integrated nutrient managements in sweet potato.

The data were subjected to the analysis of variance (ANOVA) appropriate the design and test of significance of the treatment difference was done on the basis of F test (Gomez and Gomez, 1984). The treatments were compared with the help of critical difference, following the techniques described by (Panse and Sukhatme, 1967) [24] and results were evaluated at 5% level of significance.

Results and Discussion

Growth parameters

The effect of different treatments on the growth parameters of sweet potato are given in Table 2. Application of different organic and inorganic fertilizers rates leads to significant differences in most the growth parameters except days taken to bud initiation.

It was observed that the days taken to bud initiation influenced non-significantly due to various organic treatments. However, a higher day to initiation of buds was recorded under T_1 (FYM @ 20 t/ha) followed by T_2 (Poultry manure @ 5t/ha) and T_4 {Vermicompost @5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} as compared rest of the organic treatments. Data also revealed that T_7 {FYM @ 10 t/ha + Poultry manure @2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} treatments recorded lowest number of days taken to initiation of buds. These results are in accordance with Abdissa *et al.*, (2012) [1].

Treatment T_{11} {Recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)} recorded maximum number of leaves was statistically at par with T_7 {FYM @ 10 t/ha + Poultry manure @2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} treatment and significantly better over rest of the treatments. The minimum number of leaves was recorded in treatment T_2 (Poultry manure @ 5t/ha) with a value of 180.60. Mukhtar *et al.*, (2010) [15] and Adeyeye *et al.*, (2016) [3] also reported the similar findings.

The maximum size of leaf area of (30.30 cm^2) was found in treatment T_{11} {Recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)} which was statistically at par with treatments T_7 {FYM @ 10 t/ha + Poultry manure @2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} and T_6 {FYM @ 10 t/ha + Neem cake @1 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} and significantly superior over rest of the treatments. These kind of results also obtained by Ghosh and Das (1998) [9]; Sood and Sharma (2001) [28]; Amara and Mourad (2013) [5]; Koodi *et al.*, (2017) [13].

The treatment T_{11} {Recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)} produced maximum foliage weight per plant, number of vine per plant and inter nodal length with mean value of 432.90 g, 10.68 and 4.10 cm respectively, which was statistically at par with T_7 {FYM @ 10 t/ha + Poultry manure @2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} and T_6 {FYM @ 10 t/ha + Neem cake @1 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)}. Higher levels of nutrients and a helped in cell elongation of stem due to development of cell and rapid cell division and cell elongation in meristematic region of plant. Similar results were also reported by Agbede (2011) [4] Nongmaithem and Pal (2011) [20].

The minimum number of vine per plant was recorded in T_4 {Vermicompost @5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)}. However, the minimum foliage weight per plant and inter nodal length were found with the application of T_2 (Poultry manure @ 5t/ha). Similar findings has been reported by Panigraphi and Behera (1993) [23]; El Gamal (1996) [8]; Sood and Sharma (2001) [28]; Panwar and Wani (2014) [25].

Yield parameters

Yield per hectare and their related characters were affected by various integrated organic treatments have been presented in Table 2. Different treatments have their significant impact of number of tubers per plant. The maximum number of tubers (4.0/plant) were noted under 2 treatments viz., T_{11} {Recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)} and T_6 {FYM @ 10 t/ha + Neem cake @ 1 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha) + PSB (5 kg/ha)} treatment which was at par with T_7 {FYM @ 10 t/ha + Poultry manure @2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)}. It is obvious from the table that minimum value was noted under T_2 (Poultry manure @ 5t/ha). These kind of results also obtained by Imam and Badawy (1978) [11]; Yadav *et al.*, (2003) [30]; Raghav and Kamal (2009) [26]; Sharma and Sharma (2011) [27].

The perusal of data obviously indicated that tuber weight influenced significantly due to various organic treatments. T_5 {FYM @ 10 t/ha + Vermicompost 2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} treatment produced maximum

weight of tuber (109.12 g) followed by T_7 {FYM @ 10 t/ha + Poultry manure @2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} and T_8 {Vermicompost @ 2.5 t/ha + Neem cake @ 1 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)}. However, minimum tuber weight *i.e.* 95.38 g was observed in the treatment T_6 {FYM @ 10 t/ha + Neem cake @ 1 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha) + PSB (5 kg/ha)}. Raghav and Kamal (2009) [26]; Zaman (2011) [32] also reported the similar findings.

Treatment T_{11} {recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)} produced maximum fresh weight of tuber per plant (409.50 g) that was statistically at par with T_7 {FYM @ 10 t/ha + Poultry manure @2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} and significantly superior over the rest of treatments. The minimum fresh tuber weight per plant was observed with the treatment T_2 (Poultry manure @ 5t/ha). These results are in accordance with Mukhtar *et al.*, (2010) [15]; Yourtchi *et al.*, (2013) [31]; Adeyeye *et al.*, (2016) [3].

The maximum length of tuber (16.15) cm was noted with treatment T_{11} {Recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)} which was statistically at par with T_7, and T_6 and significantly superior over rest of the treatments. However, the minimum length of tuber *i.e.* 11.87 cm was observed in plots receiving T_2 (Poultry manure @ 5t/ha). Treatments T_5 {FYM @ 10 t/ha + Vermicompost 2.5 t/ha + *Azospirillum*5 kg/ha + PSB 5 kg/ha)} produced maximum diameter of tubers (6.47) cm which was significantly superior over the rest of treatments. Similar findings has been reported by Yourtchi *et al.*, (2013) [31].

Highest tuber yield per ha (240.44 q/ha) was recorded under treatment T_{11} {recommended dose of FYM and NPK 10 t/ha and 50:25:50 kg NPK/ha)} which was significantly at par with T_7 {FYM @ 10 t / ha + Poultry manure @ 2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} and T_5 {(FYM @ 10 t / ha + RDF + 1 t/ha Neem cake)}. Similar results were also reported by Byju and Ravindran (2009) [7]; Yadav *et al.*, (2003) [30]; Raghav and Kamal (2009) [26]; Zaman (2011) [32]; Narayan *et al.*, (2013) [16]; Nedunchezhiyan *et al.*, (2010) [19]; Sowley *et al.*, (2015) [29]. However, minimum tuber yield per hectare *i.e.* 176.73q was recorded under T_2 {Poultry manure @ 5t/ha} treatment.

Table 1: Different integrated organic treatments with their respective doses

Treatment	Doses
T_1	FYM @ 20 t/ha
T_2	Poultry manure @ 5t/ha
T_3	Neem cake @ 4 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)
T_4	Vermicompost @5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)
T_5	FYM @ 10 t/ha + Vermicompost 2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)
T_6	FYM @ 10 t/ha + Neem cake @1 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)
T_7	FYM @ 10 t/ha + Poultry manure @2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)
T_8	Vermicompost @ 2.5 t/ha + Neem cake @ 1 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)
T_9	Vermicompost @ 2.5 t/ha + Poultry manure 2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)
T_{10}	1/2 Recommended dose of Fertilizers + *Azospirillum* (2.5 kg/ha) + PSB (2.5 kg/ha)
T_{11}	Recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)

Table 2: Effect of different integrated organic treatments for growth, yield and its related traits of sweet potato

Treatment	Days to initiation of buds	Number of leaves per plant	Leaf area (cm^2)	Foliage weight per plant	Number of vine per plant	Inter nodal length (cm)	Number of tuber per plant	Tuber Weight (g)	Fresh weight of tuber per plant (g)	Length of tubers (cm)	Diameter of tubers (cm)	Yield per hectare (q)
T_1	6.93	204.80	23.38	362.60	8.13	3.41	3.51	95.03	313.01	13.41	5.12	201.36
T_2	3.95	181.60	21.27	318.20	6.52	3.01	3.00	100.33	301.00	11.81	6.35	116.73
T_3	5.20	201.60	25.86	355.20	7.86	3.36	3.40	98.82	316.00	13.25	5.17	157.28
T_4	4.03	166.90	26.05	329.30	5.73	3.14	3.15	98.89	311.50	12.21	5.31	182.90
T_5	9.01	210.60	21.45	392.20	9.20	3.71	3.40	109.12	311.00	14.63	6.47	217.83
T_6	6.27	208.90	28.23	403.30	9.61	3.83	4.00	95.38	321.50	15.21	4.97	204.00
T_7	8.50	215.20	29.01	414.40	10.01	3.92	3.60	103.89	342.00	15.41	6.1	210.16
T_8	6.60	196.40	24.35	347.80	7.60	3.29	3.20	101.81	324.00	12.91	5.11	193.17
T_9	8.33	191.10	23.57	336.70	7.19	3.19	3.00	103.17	318.50	12.51	6.3	187.01
T_{10}	8.50	214.20	26.42	377.40	8.67	3.57	3.50	101.00	357.00	14.08	5.7	209.68

Conclusion

Therefore, it is concluded that, T_{11} {Recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)} was observed best treatment for growth related traits. For yield related traits, treatment T_{11} {Recommended dose of FYM and NPK (10 t/ha and 50:25:50 kg NPK/ha)} could be more significant for number of tuber per plant, fresh weight of tubers per plant, length of tubers and yield per hectare. Whereas T_5 {FYM @ 10 t/ha + Vermicompost 2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} for tuber weight and diameter of tubers. While in case of all organic sources, treatment T_7 {FYM @ 10 t / ha + Poultry manure @ 2.5 t/ha + *Azospirillum* (5 kg/ha) + PSB (5 kg/ha)} might be used for improving growth and yield along with related traits of sweet potato.

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