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Dry Matter Production and Partitioning, Yield, Quality and Nutrient Uptake of Sweet Potato (*Ipomoea batatas* L.) as Influenced by Irrigation and Fertilizer Levels

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Abstract

A field experiment was conducted for two *rabi* seasons at the Instructional Farm, Krishi Vigyan Kendra, Orissa University of Agriculture and Technology, Barachana, Odisha to study the effect of irrigation and fertilizer levels on dry matter production and partitioning, yield, quality and nutrient uptake of sweet potato (*Ipomoea batatas* L.). The experiment was conducted in split plot design with three replications. The irrigation levels were assigned to main plots (I_1 = IW/CPE 0.6, I_2 = IW/CPE 0.8, I_3 = IW/CPE 1.0 and I_4 = IW/CPE 1.2) and fertility levels to sub plots (F_1 = N-P_2O_5-K_2O @ 0-0-0 kg ha^{-1}, F_2 = N-P_2O_5-K_2O @ 50-50-50 kg ha^{-1}, F_3 = N-P_2O_5-K_2O @ 50-50-75 kg ha^{-1}, F_4 = N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1}, F_5 = N-P_2O_5-K_2O @ 75-50-100 kg ha^{-1} and F_6 = N-P_2O_5-K_2O @ 75-50-125 kg ha^{-1}). The results revealed that dry matter accumulation in leaves and stems was greater with irrigation at IW/CPE 1.2 and N-P_2O_5-K_2O @ 75-50-125 kg ha^{-1}. The dry matter accumulation in tuber was greater with irrigation at IW/CPE 0.8. The application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} resulted in greater tuber yield. The maximum tuber yield and nutrient uptake (NPK) were obtained with the application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} at IW/CPE 0.8. The starch and protein contents increased with increase in irrigation levels up to IW/CPE 1.0. The starch content in tuber increased up to N-P_2O_5-K_2O @ 75-50-100 kg ha^{-1} and that of protein content up to N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1}. The sugar content, vitamin C and β- carotene contents were found progressively declined with added irrigation and fertility levels. Thus, irrigation at IW/CPE 0.8 with application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} resulted in greater gross return, net return and B: C ratio.

Key words: Dry matter production, fertility level, irrigation, sweet potato, tuber yield, nutrient uptake.

Introduction

Sweet potato (*Ipomoea batatas* L.) is a starchy tuber consumed after boiling or baking or as vegetable. The tuber being rich in starch is increasingly used as a raw material for industries, as well as fish, poultry and animal feed. Globally, sweet potato is cultivated in 8.4 million ha with an annual production of 106.6 million tonnes and productivity of 12.8 t ha^{-1} (FAOSTAT, 2014). Asia ranking first in sweet potato cultivation occupies nearly 87% of the world sweet potato area. Among the Asian countries, China is the largest producer. In India, it is grown in 1.06 lakh ha producing 0.94 million tonnes with a productivity of 8.89 t ha^{-1} (FAOSTAT, 2014); more than 80% area is confined to the states like Odisha, Bihar, West Bengal and Uttar Pradesh (Nedunchezhiyan and Byju, 2005). In the southern, eastern and north-eastern regions of India, sweet potato occupies an inevitable position in the socio-economic conditions of small and marginal farmers.

Sweet potato, the versatile crop, is grown throughout the year in India with supplemental irrigation during dry season. It has the capacity to withstand drought. But, tuber development and bulking is extremely sensitive to both deficit as well as excess water. Under conducive environment like unlimited water availability, rich sunshine and fertile edaphic conditions sweet potato produces abundant vegetative growth. Ravindran and Nambisan (1987) reported that excess as well as deficit water adversely affected the tuber yield. Therefore water relation is of prime importance in regulating the tuber yield in sweet potato. Sweet potato is an irrigation responsive crop (Hammett et al., 1982). Both high and low levels of irrigation restricted dry matter production rate in early tuber initiation and bulking phase resulting in reduction of tuber yield (Ravi and Saravanan, 2001). Ghuman and Lal (1983) observed that application of irrigation at IW/CPE 1.0 resulted in highest dry matter production. But, increasing the soil moisture status beyond IW/CPE 1.0 resulted in reduction of dry matter production. Crops which build large food reserves in a short period require nutrients in large quantities. Therefore, the nutrient requirement of sweet potato is fairly high because of its high dry matter production per unit area per time. It is estimated that approximately 41 kg N, 13 kg P, 68 kg K, 22 kg Ca and 18 kg Mg are required to produce 18 tonnes of sweet potato per ha (Mohankumar and Nair, 1990). Sweet potato does not respond to fertilizer unless adequate amount of moisture is available in the soil.

The available literature revealed that there is not much information on the effect of fertilizer levels at excess or deficit moisture levels in sweet potato. Hence, the present investigation was carried out to find out the effect of irrigation and fertilizer levels on dry matter production and partitioning, yield and nutrient uptake of sweet potato.

Materials and Methods

A field experiment was conducted for two *rabi* (October-January) seasons (2002-03 and 2003-04) at the Instructional Farm, Krishi Vigyan Kendra, Orissa University of Agriculture and Technology, Barachana, Odisha (20°41’5" N latitude and 86°7’8"E longitude at an elevation of 25.1 m above mean sea level). The site is in the East and South Eastern Coastal Plain agroclimate zone and falls under the East Coastal Plains and Hills zone of humid tropics. The location is characterized by warm and moist climate with hot and humid summer with short and mild winter. The total amount of rainfall received during the cropping seasons were 42 mm (2 rainy days) in 2002-03 and 10 mm (3 rainy days) in 2003-04. The soil of the experimental site is clay loam with 1.42 g cm^{-3} bulk density, 28.7% moisture at field capacity and 13.9% moisture at permanent wilting point, 7.2 soil pH, 0.36% organic carbon, 189.1 kg ha^{-1} available nitrogen, 16.9 kg ha^{-1} phosphorus and 187.4 kg ha^{-1} potassium.

The experiment was conducted in split plot design with three replications. The irrigation levels were assigned to main plots (I_1 = IW/CPE 0.6, I_2 = IW/CPE 0.8, I_3 = IW/CPE 1.0 and I_4 = IW/CPE 1.2) and fertility levels to sub plots (F_1 = N-P_2O_5-K_2O @ 0-0-0 kg ha^{-1}, F_2 = N-P_2O_5-K_2O @ 50-50-50 kg ha^{-1}, F_3 = N-P_2O_5-K_2O @ 50-50-75 kg ha^{-1}, F_4 = N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1}, F_5 = N-P_2O_5-K_2O @ 75-50-100 kg ha^{-1} and F_6 = N-P_2O_5-K_2O @ 75-50-125 kg ha^{-1}). Well decomposed FYM @ 5 t ha^{-1} was incorporated in the soil before making ridges and furrows. Half dose of nitrogen, full dose of phosphorous and half dose of potassium were applied at the time of planting as basal. The remaining half dose of nitrogen and potassium was applied 30 days after planting (DAP). The variety Sankar was used. Two hand weeding was carried out at 30 and 60 DAP. Scheduling of irrigation was done on the basis of the ratio of irrigation water depth (IW) to the cumulative pan evaporation (CPE) recorded from USWB class-A open pan evaporimeter. A fixed quantity of 40 mm water was applied at each irrigation. The irrigation water was introduced to each plot through a poly-pipe connected to an overhead preloaded tank installed at one corner of the experimental site at a height of about one meter, whose inner periphery was graduated to monitor the quantity of irrigation water. Initially only one irrigation was provided on the day following planting to facilitate root initiation. Irrigation was withdrawn a week before harvesting. The crop was harvested at 120 DAP.

Sampling for estimation of dry matter production was carried out at 30, 60, 90 and 120 DAP. Three plants were uprooted carefully from the destructive sampling area and separated into leaves, stems and tubers.

Individual plant parts were air dried and then oven dried at 60°C for 72 hours and their constant weights were recorded. The summation of the oven dry weight of leaves, stems and tubers per plant gave the total dry matter accumulation. The dry matter accumulation per hectare was calculated by taking the data per plant into account. The N, P and K contents of leaves, stems and tubers were analyzed. The plant parts used for dry matter determination were groundseparately into fine powder using a Wiley mill for chemical analysis. Nitrogen was estimated by modified micro-Kjeldahl, phosphorus by Olson's and potassium by flame photometry method (Jackson, 1973). Nutrient (N/P/K) uptake was calculated by dry matter accumulation x nutrient (N/P/K) content. Starch and sugar content of tuber was estimated by anthrone colorimetric method (Whistler and Wolfrom, 1962). Protein content was calculated by multiplying nitrogen content with 6.25. Carotene and vitamin C content of tuber was estimated as per method suggested by Ranganna (1977).

The data were subjected to analysis of variance (ANOVA) for split plot using Genstat software. Comparison of treatment means for significance at 5% was done using the critical differences (CD) as suggested by Gomez and Gomez (1984).

Results and Discussion

Dry matter production and partitioning

Dry matter accumulation is an effect of growth processes. Its accumulation in leaves and stems was gradual up to 60 DAP (Fig. 1 and 2). With increase in leaf area it increased at a faster rate up to 90 DAP and decline thereafter owing to senescence and diversion of assimilates to the storage organ. Dry matter accumulation in tuber surpassed that of leaves and stems after start of the tuber bulking. The leaf, stem and tuber contributed 21.2, 23.9 and 54.9% to the total dry matter produced at harvest (Fig. 1 and 2).

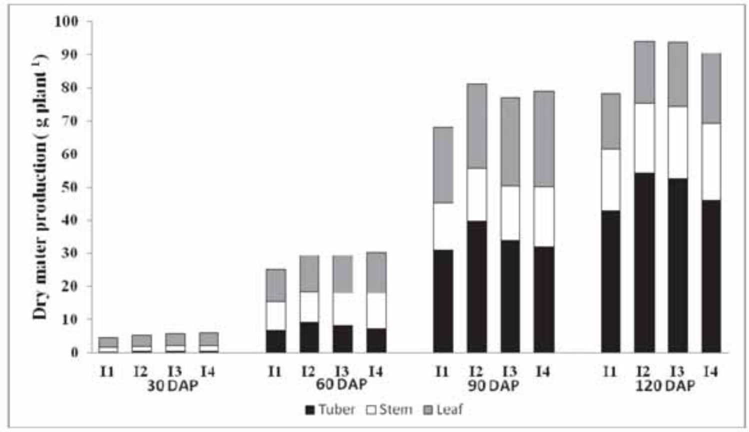

Fig. 1. Dry matter production and partitioning in sweet potato as influenced by irrigation schedule (pooled mean of 2 years)

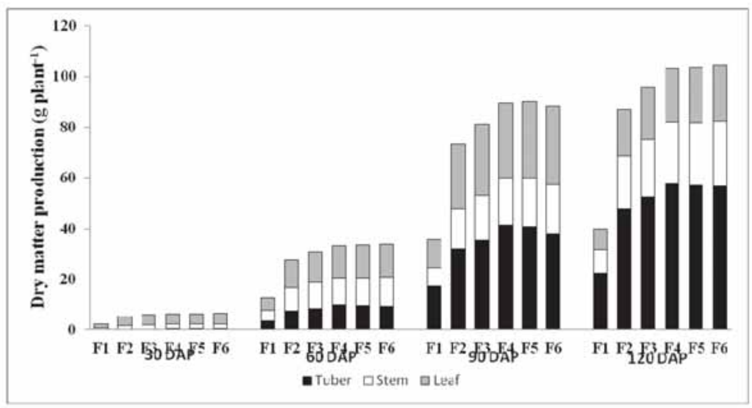

Fig. 2. Dry matter production and partitioning in sweet potato as influenced by fertility levels (pooled mean of 2 years)

Plant requires water to meet the evaporative demand, build up tissues and carry out biochemical and physiological activities (Majumdar, 2000). Irrigation and fertility levels significantly influenced dry matter accumulation in leaves, stems and tubers (Fig. 1 and 2). Dry matter accumulation in leaves and stems was greater with the application of irrigation at IW/CPE 1.2 (I_4) and N-P_2O_5-K_2O @ 75-50-125 kg ha^{-1} (F_6) (Fig. 1 and 2). This is due to better availability of moisture and nutrients. Unlike aerial parts, dry matter accumulation in tuber was greater irrigation at IW/CPE 0.8 (I_2) (Fig 1). Accumulation of dry matter was minimum and adversely affected when irrigation was further reduced at IW/CPE 0.6 (I_1) due to low moisture level and reduced photosynthesis (Kirkhan, 1990). Reduction in photosynthesis occurred due to reduction in chlorophyll content under moisture stress conditions (Indira and Kabeerathumma, 1988). Photosynthesis or translocation of photosynthates or both were affected adversely by excess water and water stress. Photosynthesis and respiration rates decreased under moisture stress conditions. But the reduction in photosynthetic rate was much greater than that of respiration rate. High photorespiration attributed to the loss of fixed carbon, which resulted in decreased dry matter production (Ravi and Saravanan, 2001). The dry matter accumulation in tubers increased with an increase in fertility levels (Fig 2). Maximum dry matter accumulated in tubers with N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (F_4) as compared to the other fertility levels. It may be due to better translocation and sink-source relationship (Bourke, 1985).

Irrigation levels affected the total dry matter production significantly. Application of irrigation at IW/CPE 1.2 (I_4) produced more amount of total dry matter than the other levels up to 60 DAP (Fig. 1). At 90 and 120 DAP, irrigation at IW/CPE 0.8 (I_2) produced greater amount of total dry matter than the other levels due to higher amount of dry matter accumulation in tubers. At 120 DAP, the total dry matter produced irrigation at IW/CPE 0.8 (I_2) was 0.12, 3.33 and 20.21% higher than that of irrigation at IW/CPE 1.0, 1.2 and 0.6, respectively (Table 1). Variation in total dry matter production at different levels of fertility was found to be significant. It increased with increasing levels of fertility up to N-P_2O_5-K_2O @ 75-50-125 kg ha^{-1} (F_6) at all the stages of growth (Fig. 2). At 120 DAP, the total dry matter production was maximum with the application of N-P_2O_5-K_2O @ 75-50-125 kg ha^{-1} (F_6) (Table 1). It was statistically at par with the application of N-P_2O_5-K_2O @ 75-50-100 kg ha^{-1} (F_5) and N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (F_4). The total dry matter accumulation in N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (F_4) was 19.2, 8.3 and 160% higher than F_2, F_3 and F_1 respectively at harvest (Table 1).

Application of irrigation at IW:CPE 1.0 with N-P_2O_5-K_2O @ 75-50-125 kg ha^{-1} (I_3F_6) produced greater amount of total dry matter but it was statistically at par with irrigation at IW:CPE 0.8 with N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (I_2F_4) (Table 1). The latter has produced dry matter of 8.855 t ha^{-1} due to optimum level of moisture and nutrition. This may be due to the fact that at this level of irrigation and fertility there was not only the development of source system, but also higher efficiency for photosynthesis and translocation increasing the sink capacity thus bringing an optimum balance between source and the sink (Prasad, 1971 and Hammett et al., 1982).

Tuber yield

The irrigation and fertility levels significantly influenced the tuber yield (Table 1). Irrigation at IW/CPE 0.8 (I_2) produced greater tuber yield (15.57 t ha^{-1}), . on par with irrigation at IW/CPE 1.0 (I_3) (15.43 t ha^{-1}) (Table 1). Greater yield in these treatments might be due to more yield attributes. Oommen (1989) obtained higher tuber yield under irrigation at IW/CPE 0.75. Most of the crop plants have an optimum moisture regime, beyond which their growth and yield are affected adversely due to poor oxygen availability in the effective root zone. On the other hand, moisture absorption lags behind transpiration under moisture stress condition, resulting in reduction of plant growth and yield (Gomes and Carr, 2003). Further increase in irrigation level reduced the tuber yield. The lowest tuber yield was recorded at IW/CPE 0.6 (I_1) (Table 1). The tuber formation was considerably influenced by the level of moisture around the root zone. The yield decreased due to shortage of moisture at IW/CPE 0.6 (I_1). Increase in IW/CPE from 0.6 to 0.8 increased the tuber yield by 30%, which was at par with irrigation at IW/CPE 1.0 (I_3). Roy Chowdhury et al. (2001) reported an increase in tuber yield with increase in irrigation levels IW/CPE from 0.3 to 0.9. Further increase in irrigation level at IW/CPE 1.2 (I_4) reduced the tuber yield by 11%. Chowdhury (1996) also reported decreased tuber yield by 62% by increase in irrigation level from IW/CPE of 1.0 to 0.2.

Marked variation in tuber yield was noticed when fertility level increased (Table 1). The treatment N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (F_4) resulted in higher tuber yield (Table 1). Further increase in fertility level reduced the tuber yield by 1.3% and 1.9% with (F_5) and (F_6) respectively, which was statistically at par with the application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (F_4). Nedunchezhiyan and Byju (2005) and Nath et al. (2007) reported maximum number of tubers and yield at N @ 75 kg ha^{-1}. George and Mitra (2001) reported potassium application beyond 100 kg ha^{-1} was insignificant. Nair and Nair (1992) obtained maximum tuber yield with the application of K_2O @ 75 kg ha^{-1}. Balanced application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} contributed maximum yield at New Delhi (Dayal and Sharma, 1993) and Bhubaneswar (CTCRI, 1977).

The interaction effect of irrigation and fertility levels on tuber yield was significant (Table 1). The highest tuber

Table 1. Effect of irrigation and fertilizer levels on tuber and vine yield, nutrient uptake and economics of sweet potato (pooled mean of 2 years)

Treatment	Total dry matter (t ha^{-1})	Tuber yield (t ha^{-1})	NPK uptake (kg ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C Ratio
Irrigation (IW/CPE)						
I1 = 0.6	6.243	11.99	172	35963	18285	2.03
I2 = 0.8	7.505	15.57	226	46720	28542	2.57
I3 = 1.0	7.496	15.43	233	46291	27113	2.41
I4 = 1.2	7.263	13.93	216	41792	21864	2.10
SEm ±	0.053	0.17	3.0	329	327	0.01
CD (0.05)	0.182	0.59	9.0	1124	1118	0.03
Fertility level ($N-P_2O_5-K_2O$ kg ha^{-1})						
F1 = 0-0-0	3.188	6.58	66	19734	2921	1.17
F2 = 50-50-50	6.952	13.91	187	41715	23023	2.23
F3 = 50-50-75	7.649	15.26	224	45793	26900	2.42
F4 = 75-50-75	8.284	16.72	273	50163	31015	2.62
F5 = 75-50-100	8.288	16.51	269	49519	30170	2.56
F6 = 75-50-125	8.398	16.41	249	49224	29676	2.52
SEm ±	0.043	0.13	3.0	358	359	0.01
CD (0.05)	0.122	0.37	7.0	1023	1013	0.03
I x F interaction						
I1F1	2.810	5.25	55	15736	-14	1.00
I1F2	6.246	11.94	154	35833	18203	2.03
I1F3	6.742	12.89	183	38667	20837	2.17
I1F4	7.130	14.18	216	42551	24465	2.35
I1F5	7.208	13.91	222	41742	23456	2.28
I1F6	7.323	13.75	201	41244	22758	2.23
I2F1	3.130	6.13	67	18393	2143	1.13
I2F2	7.354	14.95	201	44860	26730	2.47
I2F3	8.096	16.78	241	50343	32013	2.75
I2F4	8.855	18.89	297	56665	38079	3.05
I2F5	8.769	18.48	285	55439	36653	2.95
I2F6	8.826	18.21	264	54630	35644	2.88
I3F1	3.022	6.35	64	19049	1799	1.10
I3F2	7.115	14.68	202	44047	24917	2.30
I3F3	8.003	16.55	243	49658	30328	2.57
I3F4	8.923	18.62	308	55857	36271	2.85
I3F5	8.873	18.25	299	54762	34976	2.77
I3F6	9.043	18.12	280	54360	34374	2.72
I4F1	3.789	8.59	77	25757	7757	1.43
I4F2	7.094	14.04	191	42120	22240	2.12
I4F3	7.757	14.83	228	44503	24423	2.22
I4F4	8.230	15.57	272	46707	26371	2.30
I4F5	8.301	15.31	272	45935	25399	2.24
I4F6	8.399	15.24	253	45735	24999	2.21
SEm ±	0.085	0.26	5	716	718	0.01
CD (0.05)	0.244	0.74	15	2046	2026	0.04

Treatment details are given in Materials and Methods yield was obtained under irrigation at IW/CPE 0.8 with the application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (I_2F_4) (Table 1). It was statistically at par with the tuber yield obtained at the same level of fertility and irrigation at IW/CPE 1.0 (I_3F_4) and with higher level of fertility at the same level of irrigation (I_2F_5). The yield of I_2F_4 was also found statistically at par with higher fertility levels (I_2F_5 and I_2F_6) at the same level of irrigation (Table 1). The higher tuber yield in these treatments might be due to greater yield attributes. Higher tuber yield in these treatments might be due to early tuber initiation under congenial micro-environment with perfect air-water balance facilitating greater nutrient and energy transport for tuber growth. Low moisture under irrigation at IW/CPE 0.6 must have reduced the tuber growth due to high compactness led penetration resistance (Chowdhury et al., 2002). At higher irrigation level, energy shift for vegetative growth (Fig.1) might have adversely affected the tuber growth (Fig.1). Inadequate supply of oxygen at high moisture level and poor absorption and translocation due to path way resistance at low moisture level might have reduced the nutrient uptake. It adversely affected the tuber bulking rate by poor cell division and expansion through low starch accumulation resulting in lower tuber yield (Chowdhury, 1995).

Nutrient uptake

The movement of nutrients to the root zone is influenced by the soil moisture status and the potential gradient created at the root surface. Availability of nutrients and absorption capacity of the plant decide the nutrient content in plants, which is manifested in crop yield. Maximum amount of NPK was accumulated in tubers and minimum in leaves. Potassium constituted 59%, nitrogen 33% and phosphorus 8% of the total amount of nutrients taken up by the plant.

The N, P and K uptake in leaf and stem was greater at high irrigation level (IW/CPE 1.2) due to higher aerial dry matter production and poor tuber development (Table 2). The uptake by tuber was greater at IW/CPE 0.8 (I_2) (Table 2). This implies that the sink strength is enhanced and more important under optimum moisture and nutrient conditions (Kuo and Chen, 1992; Dayal and Sharma, 1993). Further increase in irrigation level at IW/CPE 1.2 (I_4) might have broken the air water balance leading to inadequate moisture availability under limited oxygen supply and thereby reducing the absorption and nutrient contents in different plant parts. Frequent irrigation might have also caused nutrient leaching and increased the dilution effect (Sardana, 2000). With low soil moisture, the water films around soil particles get thinner and discontinuous resulting in a torturous path way for mass flow of nutrients to plant roots. At low irrigation level (IW/CPE 0.6), there might be reduction in nutrient availability, absorption and transportation due to turgor induced path way resistance in the plant and surface tension in the soil (Indira, 1989). At high or low moisture level, the availability of nutrients might not change appreciably but the utilization differed (Samuels, 1967). As a result of which the uptake decreased at IW/CPE 1.2 and 0.6 as compared with 0.8. The N, P and K uptake and the total NPK uptake was greater at IW/CPE 1.0 but was at par with 0.8. This might be due to better nutrient use efficiency resulting in high yield and greater share of tuber in total dry matter production in case of the latter.

Total N and K uptake was greater with N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (F_4) (Table 2). Total P uptake was greater with N-P_2O_5-K_2O @ 75-50-100 kg ha^{-1} (F_5) which was at par with 75-50-75 kg ha^{-1} (F_4) (Table 2). The N and K uptake increased with increase in N levels. Since nitrogen is highly mobile, its availability in soil solution increased the uptake of N by the crop. Similar trend was noticed by Satapathy et al. (2005). Further increase in fertility level at F_6 reduced the uptake. Decrease in utilization of nutrients at higher fertility level might be due to the law of diminishing return (Tisdale et al., 1990). The total uptake of nutrients (NPK) was greater with N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (F_4) which was at par with F_5 due to greater availability of nutrients at the root zone leading to higher uptake in balanced proportion at a congenial micro environment at the root rhizosphere (Nedunchezhiyan and Reddy, 2004). With increase in N levels the P uptake increased due to increase in dry matter accumulation. The K uptake increased due to N and K interaction effect with better availability of K from supplied K fertilizer and soil K reserve (Goswami et al., 1995 and Satapathy et al., 2005). At higher N level, the P and K uptake increased proportionately to enhance the growth and yield parameters. The tuber yield was greater at IW/PE 0.8 with the application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1}(I_2F_4) (18.89 t ha^{-1}) which removed NPK 297 kg ha^{-1} (N 99 kg, P 22 kg and K 176 kg). For production of

Table 2. Effect of irrigation and fertilizer levels on N, P and K uptake of sweet potato (pooled mean of 2 years)

Treatment	Nitrogen ($kg\ ha^{-1}$)				Phosphorus ($kg\ ha^{-1}$)				Potassium ($kg\ ha^{-1}$)			
	Leaf	Stem	Tuber	Total	Leaf	Stem	Tuber	Total	Leaf	Stem	Tuber	Total
Irrigation (IW/CPE)												
I1 = 0.6	11.8	13.6	33.8	59.1	4.2	4.1	5.2	13.5	24.3	27.8	47.1	99.2
I2 = 0.8	14.0	16.2	45.1	75.3	5.3	5.2	7.4	17.8	31.0	34.8	66.9	132.7
I3 = 1.0	15.1	17.0	44.6	76.6	5.7	5.4	7.3	18.4	33.9	36.9	66.9	137.7
I4 = 1.2	15.4	17.7	36.4	69.5	6.1	5.9	6.3	18.3	34.6	38.6	54.6	127.8
SEm ±	0.14	0.20	0.62	0.85	0.05	0.04	0.11	0.20	0.34	0.31	1.04	1.61
CD (0.05)	0.50	0.70	2.16	2.93	0.19	0.15	0.39	0.68	1.19	1.09	3.61	5.59
Fertility level ($N-P_2O_5-K_2O$ $kg\ ha^{-1}$)												
F1 = 0-0-0	4.6	5.3	13.7	23.6	1.9	1.9	2.5	6.3	8.1	10.4	17.4	35.9
F2 = 50-50-50	12.3	14.1	34.7	61.1	4.9	4.8	6.0	15.7	27.3	31.1	52.1	110.5
F3 = 50-50-75	14.7	16.7	41.4	72.8	5.7	5.4	6.9	18.0	33.3	36.9	62.7	132.9
F4 = 75-50-75	17.7	20.1	51.7	89.5	6.3	6.1	8.1	20.5	40.7	44.1	78.5	163.3
F5 = 75-50-100	17.7	20.1	49.9	87.7	6.6	6.3	8.0	20.9	40.7	44.1	76.0	160.8
F6 = 75-50-125	17.5	20.2	48.5	86.1	6.5	6.4	7.8	20.7	35.7	40.5	66.4	142.6
SEm ±	0.16	0.18	0.49	0.81	0.06	0.06	0.08	0.19	0.38	0.42	0.83	3.19
CD (0.05)	0.45	0.51	1.41	2.32	0.17	0.16	0.23	0.55	1.10	1.19	2.36	9.11

Treatment details are given in Materials and Methods

one tonne of tuber, the crop removed 5.2 kg N, 1.2 kg P and 9.4 kg K at the ratio of 4.3-1.0-7.8. Sreelatha et al. (1996) estimated that to produce one tone of sweet potato tuber 12.4 kg N, 1.0 kg P and 10.7 kg K were required. At higher irrigation levels more mobile N and K favoured more vegetative growth (Chowdhury et al., 2002). Dayal and Sharma (1993) observed that liberal application of irrigation at IW/CPE 1.0 along with N and K_2O @ 100 kg ha^{-1} resulted in greater vegetative growth.

Tuber quality

Sweet potato is a nutraceutical food. It is a store house of carbohydrates, minerals, vitamin C and β-carotene. The starch and protein contents increased with increase in irrigation level up to IW/CPE 1.0 (I_3) (Table 3). Maximum starch and protein contents were recorded at this level, which decreased with further increase in irrigation level. Its translocation to sink is better at optimum moisture level than the others (Mishra et al., 1990). At low moisture level, decrease in starch content has been reported by Indira and Kabeerathumma (1990). The protein content increased in pace with the nitrogen uptake favoured by balanced N and K absorption at IW/CPE 1.0 (Patil et al., 1990). The nitrogen content decreased with frequent irrigation at IW/CPE 1.2 due to leaching; at low moisture level its availability, absorption and transportation was restricted resulting in low protein content (Nair and Nair, 1992). High protein content at IW/CPE 1.0 might be due to accumulation of non-protein nitrogen fraction which was not utilized by the plants, and thus tapped in course of chemical analysis (Behura, 2002).

The starch content in tuber increased up to $N-P_2O_5-K_2O$ @ 75-50-100 kg ha^{-1} (F_5) and that of protein content up to $N-P_2O_5-K_2O$ @ 75-50-75 kg ha^{-1}(F_4) (Table 3). It decreased thereafter at high fertility levels. The degree of variation in metabolic and enzymatic activities responds up to a certain level of fertility. High starch content with high level of K and high protein content at high level of N have also been reported by Mukhopadhyay et al., (1993) and Patil et al.,

Table 3. Effect of irrigation and fertilizer levels on quality of sweet potato tubers (pooled mean of 2 years)

Treatment	Starch (%)*	Sugar (%)*	Protein (%)*	β-carotene * (mg 100 g^{-1})	Vitamin C (mg 100 g^{-1})*
Irrigation (IW/CPE)					
I1 = 0.6	58.60	12.78	6.14	2.39	66.89
I2 = 0.8	61.56	12.30	6.50	2.37	66.18
I3 = 1.0	62.53	12.11	6.61	2.34	65.05
I4 = 1.2	60.09	11.56	6.19	2.34	64.56
SEm ±	0.46	0.07	0.02	0.02	0.40
CD (0.05)	1.60	0.25	0.07	NS	1.39
Fertility level (N-P_2O_5-K_2O kg ha^{-1})					
F1 = 0-0-0	51.04	13.64	4.79	2.46	66.66
F2 = 50-50-50	60.21	12.60	5.70	2.45	66.33
F3 = 50-50-75	61.98	12.11	6.17	2.43	65.55
F4 = 75-50-75	62.85	11.97	7.01	2.39	65.35
F5 = 75-50-100	64.80	11.67	6.83	2.34	65.30
F6 = 75-50-125	63.88	11.15	6.67	2.10	64.81
SEm ±	0.42	0.09	0.01	0.02	0.52
CD (0.05)	1.20	0.27	0.02	0.05	1.48

*Dry weight basis (Treatment details are given in materials and methods)

(1990). Increase in starch and protein contents with increase in potassium and nitrogen uptake has been observed by Bartolini (1982), Nair and Nair (1992) and Roy Chowdhury et al., (2001), which was confirmed in the present study.

Unlike starch, the sugar content declined with increasing irrigation level along with vitamin C and β-carotene (Table 3). The highest contents of sugar, vitamin C and β-carotene were recorded with irrigation at IW/CPE 0.6 (I_1) (Table 3). A decrease in these parameters was due to the dilution effect with an increase in the moisture level as high moisture activated the nitrogen favouring reversion of sugar. Higher vitamin C and β-carotene content at low moisture level has also been reported by Indira and Kabeerathumma (1990) and Hammett et al. (1982). The sugar content, vitamin C and β-carotene contents were found maximum in non fertilized treatments, which progressively declined with added fertility levels (Table 3). It is because of the dilution effect on synthesis and accumulation of vitamins due to increased dry matter production at high fertility levels. Increased nutrition enhanced the nitrogen activity adversely affecting sugar build up. Significantly decrease in sugar content with increasing levels of nitrogen was also noticed by Mishra et al. (1990).

Economics

Irrigation and fertility levels significantly influenced sweet potato economics (Table 1). The treatment IW/CPE 0.8 (I_2) resulted in greater gross return, net return and B: C ratio. This was due to greater tuber yield (15.57 t ha^{-1}). The treatment N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (F_4) resulted in greater gross return, net return and B: C ratio. This was due to greater tuber yield (16.72 t ha^{-1}) (Table 1). The highest gross return of Rs 56665 and net return of Rs 38079 ha^{-1} with benefit cost ratio of 3.05 was realized from irrigation at IW/CPE 0.8 with application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} (I_2F_4) due to efficient and optimum utilization of water and nutrient resources resulting in greater tuber production (18.89 t ha^{-1}). Similar results were reported by Kuruvilla et al. (1987), Elizabeth and Kunju (1989) and Nedunchezhiyan and Reddy (2002).

Conclusion

Irrigation and fertility levels significantly influenced sweet potato dry matter production, partitioning, tuber yield, quality and nutrient uptake. Dry matter accumulation in leaves and stems was greater with irrigation at IW/CPE 1.2 and N-P_2O_5-K_2O @ 75-50-125 kg ha^{-1}. The dry matter accumulation in tuber was greater with irrigation at IW/CPE 0.8. The application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} resulted in greater tuber yield. The maximum tuber yield and nutrient uptake (NPK) were obtained with the application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} at IW/CPE 0.8. The starch and protein contents increased with increase in irrigation level up to IW/CPE 1.0. The starch content in tuber increased up to N-P_2O_5-K_2O @ 75-50-100 kg ha^{-1} and that of protein content up to N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1}. The sugar content, vitamin C and β-carotene contents progressively declined with added irrigation and fertility levels. The treatment irrigation at IW/CPE 0.8 with application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} resulted in greater gross return, net return and B: C ratio. Thus, the treatment irrigation at IW/CPE 0.8 with application of N-P_2O_5-K_2O @ 75-50-75 kg ha^{-1} may be recommended to farmers for greater tuber yield, optimum quality and efficient utilization of water and nutrient resources.

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