Studies on crop residue production of cape gooseberry (*Physalis peruviana* L.) and physico-chemical properties of sodic soil under varying levels of plant spacing and NPK fertilizers

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Abstract

The cape gooseberry (*Physalis peruviana* L.), a quick growing herbaceous crop, leaves behind a good amount of crop residue in the field after fruit harvest that can be utilized as organic source of plant nutrient supply to next crop to be cultivated. In present investigation, crop residue of cape gooseberry grown in *sodic* soil of Eastern Uttar Pradesh (India) at three planting density (S_1 - 75 x 60 cm, S_2 - 75 x 75 cm and S_3 - 90 x 75 cm) and four levels of NPK fertilizers (F_0 - without fertilizers, F_1 - 60:40:40, F_2 - 80:60:60 and F_3 - 100:80:80 NPK kg ha^1) was estimated. Soil properties were also studied before and after cropping seasons. Mean data of two consecutive years recorded crop residue (fresh biomass) production 34.51, 29.7 and 27.95 t ha^{-1} at S_1, S_2 and S_3 plant spacing, respectively. The application of NPK fertilizers significantly increased crop residue production and mean value recorded with fertilizer level F_0, F_1, F_2, and F_3 was 22.00, 28.71, 34.24 and 36.63 t ha^{-1}, respectively. Increased plant population per unit area as well as higher doses of NPK levels showed a little improvement in bulk density, porosity, organic carbon, pH and EC of soil but influence was non-significant, however, plant spacing and NPK fertilizer treatments exhibited significant improvement in available nitrogen, phosphorus and potassium of the soil at the end of the second cropping season.

Key words: Cape gooseberry, crop residue, NPK fertilizers, *Physalis peruviana* L., plant spacing, soil properties

Introduction

Soil organic matter plays an important role in maintaining rhizosphere health for better growth and development of the plant. In intensive agriculture, soil often gets sick due to continuous use of chemical fertilizers; hence organic manures are used to increase efficiency of fertilizers, as the nutrient cycling in the soil-plant ecosystem has immense importance in sustainable crop production. Management of crop residues regulates the efficiency with which fertilizer, water, and other reserves are used in a cropping system. Although, during the last few decades fertilization practices have played a dominant role in the cropping systems, crop residues (the harvest remnants of the previous crop) still play an important role in the cycling of nutrients as incorporation of crop residues alters the soil environment, which in turn influences the microbial population and activity in the soil and subsequent nutrient transformations.

There are large uncertainties in the data on generation of crop residues, their uses, the remaining surplus and on-farm burning. More than 1000 Mt of cereal residues are being produced annually in the developing world (FAO, 1999). In 2000, the total agricultural residue production in India was 347 Mt (Thakur, 2003). Pathak (2004) estimated that annually about 525 Mt crop residues are available in India. Pathak *et al.* (2010) estimated that about 90 Mt of crop residues are burnt on-farm and this figure is close to 85 Mt when the coefficients developed by the Inter-Governmental Panel on Climate Change (IPCC) are used.

Crop residues have, in fact, played a pivotal role in the maintenance of soil resources at acceptable levels because these are the major sources of inputs. Crop residue management is known to affect either directly or indirectly most of the soil quality indicators: chemical, physical and biological characteristics. In addition to their role as the primary source of inputs, crop residues, and the way they are managed, have a significant impact on soil physical properties (Boyle *et al*., 1989). The removal of crop residues leads to low soil fertility and thereby decreased crop production efficiency. Effective management of residues, roots, stubble, and weed biomass can have a beneficial effect on soil fertility through the addition of organic matter and plant nutrients, and improvement in soil condition (Munda*,* 2006; Singh 2003; Sidhu and Beri 1989; Srivastava *et al*. 1988). According to Singh (2003) about 25% of N and P, 50% of S and 75% of K taken up by cereal crops are retained in the crop residue, making them viable nutrient sources. Also, residues return carbon to the soil, which improves soil structure, the ability of the soil to hold nutrients, and water holding capacity.

In recent years, the concept of soil quality has been suggested as a tool for assessing the long-term sustainability of agricultural practices at local, regional, national, and international levels. Besides causing environmental pollution, burning results in loss of organic carbon and plant nutrients. Increased concern for the environment and increased emphasis on sustaining soil productivity has resulted in major interest in the maintenance and improvement in soil organic matter in recent years. The increasing constraints of labor and time under intensive agriculture have led to the adoption of mechanized cropping systems. Proper management and utilization of crop residues and other agricultural waste will constitute an important factor in achieving this objective. As crop residues interfere with tillage operation,

farmers often prefer to burn/ destroy these residues. It is perceived that soil quality is improved by the adoption of good crop residue management practices. If crop residues could be better managed, this would directly improve crop yields by increasing soil nutrient availability, decreasing erosion, improving soil structure, and increasing soil water holding capacity. Suitable manipulations of processes such as nutrient immobilization are an important component of an efficient crop residue management program, allowing adequate time for decomposition of crop residues before planting the next crop can be beneficial in alleviating adverse effects due to N immobilization and phytotoxicity. Crop residues can also lead to negative effects on crop production in the short term because of N immobilization and possible release of phytotoxic compounds. However, studies in this line are scarce and require thorough investigation and needful development of sustainable crop production strategies for efficient utilization/ management of crop residues system.

The cape gooseberry (*Physalis peruviana* L.), a herbaceous quick growing fruit crop of the family Solanaceae, grown in tropical regions of world for its attractive golden colour berries. The crop is said to be native of Peru and Chile and reportedly cultivated in South Africa, Kenya, India, Egypt, New Zealand, the Caribbean, South East Asia, California, Columbia and Hawaii (Legge, 1974; Klinac, 1986; Chattopadhyay, 1996). It is commonly called as 'Poha' in Hawaii, 'Golden berry' in South Africa, 'Rasbhari', 'Makoi' or 'Tepari' in India (Gupta and Roy, 1980). In India, it is a minor crop and mostly grown in peri-urban areas. After cropping cycle a large quantity of crop residue left over the field that may be utilized for nutrients cycling in cropping system. In present experiment, an estimation of crop residue of cape gooseberry grown under varying levels of NPK and plant spacing in *sodic* soils of eastern Uttar Pradesh was carried out to understand the role of crop residue produced by goosebery in relation to sustainable crop production.

Materials and methods

The study was conducted at Main Experiment Station, Department of Horticulture, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (Uttar Pradesh), India (latitude 26.47^0 N, longitude 82.12^0 E and 113 m elevation). This site is characterized by sub-humid and sub-tropical climate observing mean annual rainfall 1190 mm, mainly received during July to September. However, the occasional showers due to North-East monsoon during winter (October-mid February) and sometimes in summer (April-mid June) are also not uncommon. The summer months are hot, dry and desiccating. Winter commences from October with peak around Farewell-Welcome of the two years. The investigation was conducted during two consecutive cropping seasons during year 2004 to 2006. Soil sample (0 to 30 cm depth) of experiment field was analyzed for initial physico-chemical properties (Table 1). Twenty six days old seedling of cape gooseberry (S-101 genotype obtained from Suttind Seeds Pvt. Ltd, New Delhi) were transplanted on August 10, 2004 and August, 9, 2005 in well prepared open field for the year 2004-05 and 2005-06 experiments, respectively. The size of individual plots was 9.0 x 3.0 m. The spacing treatments were S_1 - 75 x 60 cm, S_2 - 75 x 75 cm and S_3 - 90 x 75 cm, and NPK levels F_1 - control, F_2 - 60:40:40, F_3 - 80:60:60 and F_4 - 100:80:80 NPK kg ha^{-1}, respectively. The experiment was layout in Spit Plot Design wherein main plot was assigned with spacing treatments and sub-plot with NPK fertilizers. The source for nitrogen, phosphorus and potassium fertilizers was urea (N 46%), single super phosphate (16% P_2O_5) and murate of potash (60% K_2O). One-third nitrogen and full amount of phosphorus and potassium were applied during last preparation of experimental soil. Remaining quantity of nitrogen was divided into two equal parts and top dressed at 60 and 75 days after transplanting.

Data on fresh weight and dry matter of plant was recorded at end of the fruiting seasons in both the years. Plants were uprooted along with entire roots and their fresh weight was taken with the help of electronic balance. After weighing the fresh weight of plant they were sun dried for three days and subsequently kept in electric oven at the temperature of 70 ^{0}C till the sample attained a constant weight. The final weight of these oven dried samples was recorded by electronic balance. At the end of fruiting seasons in both the years, the crop residue (fresh biomass) production per hectare was estimated from the crop residue harvested from each experimental plot and expressed in q ha^{-1}. During both the years, physico-chemical properties of soil bulk density, particle density, porosity, pH, electrical conductivity, organic carbon and available nutrients (nitrogen, phosphorus and potassium) were recorded from the soil sample of each plot as per the procedure given in Table 1. Data recorded during the course of study were analyzed as per standard procedure of Panse and Sukhatme (1985) and means were compared by Duncan's multiple range test (DMRT) at 5% level of confidence.

Results and discussion

Date presented in Table 2 revealed that varying plant spacing significantly affected the fresh weight as well as dry weight of

Table 1. Physico-chemical properties of experimental soil

S. No.	Particulars	Initial value	Method employed
A.	Physical characteristics		
1.	Bulk density	1.34g cm^{-3}	Core sampler method (Bodman, 1942)
2.	Particle density	2.56g cm^{-3}	Pycnometer method (Black, 1965)
3.	Porosity	44.37 %	By formula using bulk density and particle density.
B.	Chemical characteristics		
4.	Soil reaction (pH)	8.56	Glass electrode pH meter (Jackson, 1973)
5.	Electrical conductivity	0.42 dSm^{-1}	Conductivity Meter (Jackson, 1973)
6.	Organic carbon	0.35%	Rapid titration method (Walkley and Black, 1934)
7.	Available nitrogen	190.44 kg ha^{-1}	Subbaiah and Asija (1956)
8.	Available phosphorus	17.86 kg ha^{-1}	Molybdo-phosphoric colour method (Jackson, 1973)
9.	Available potassium	229.34 kg ha^{-1}	Flame photometer method (Jackson, 1973)

cape gooseberry plants during both the years. Fresh weight of individual plant was increased with each increased plant spacing treatments. Among the three plant spacing tested under study, the highest fresh weight was recorded with widest spacing S_3 (90 x 60 cm), which was significantly superior to the fresh weight of plant achieved at S_2 (75 x 75 cm) and S_1 (75 x 60 cm) spacing during both years of study. The mean value of fresh weight of plant over two years experiment at S_1, S_2 and S_3 was 1.73 kg, 1.89 kg and 2.10 kg, respectively. Similarly, dry weight of plant was increased with each increased level of plant spacing and recoded highest with S_3 followed by S_2 and S_1 with mean dry weight 294.64 g, 261.72 g and 228.15 g plant^{-1}, respectively.

Application of NPK fertilizer resulted significant increase in fresh weight of plant (Table 2). It is evident from mean data averaged over two year study, the highest fresh weight (2.32 kg plant^{-1}) was recorded with F_3 (100:80:80 NPK kg ha^{-1}) followed by 2.17 and 1.84 kg plant^{-1} with NPK levels of F_2 (80:60:60 NPK ha^{-1}) and F_1 (60:40:40 NPK kg ha^{-1}), respectively. The lowest fresh weight of plant (1.43 kg plant^{-1}) was recorded (control). The dry weight of plant was also significantly increased with each increased level of the NPK fertilizers in both the years of study (Table 2). Mean highest dry weight of plant (309.89 g plant^{-1}) was recorded with the application of 100:80:80 NPK kg ha^{-1} followed 286.55 g, 264.24 g with 80:60:60 and 60:40:40 kg ha^{-1} of NPK fertilizers, respectively.

Unlike the effect of plant spacing on fresh weight per plant, the

crop residue production (fresh biomass) per unit area (per ha basis) showed inverse relationship with increase in plant spacing (Fig. 1a). In other words, increased plant population per unit area enhanced crop residue production per unit area. From mean data over two year study, it is evident that highest crop residue production was achieved with the spacing of 75 x 60 cm (35.93 t ha^{-1}) followed by 30.42 and 28.64 t ha^{-1} with S_2 (75 x 75 cm) and S_3 (90 x 75 cm) spacing, respectively.

Contrary to the decrease in crop biomass production per unit area with increased plant spacing, application of every increased dose of NPK fertilizers significantly enhanced the fresh biomass production per unit area (Fig. 1b) during both the years. Mean crop biomass production with F_0 (control), F_1 (60:40:40), F_2 (80:60:60) and F_3 (100:80:80 kg NPK ha^{-1}) was 21.05, 27.883, 3.23 and 37.69 t ha^{-1}, respectively.

While comparing the physico-chemical properties of experimental soil before and after study, the parameters were found slightly affected due to cape gooseberry cultivation under varying levels of plant spacing and NPK fertilizers (Table 1, 3 and 4). Bulk density, particle density and porosity of soil as affected by plant spacing and NPK fertilizers revealed that an increase in plant spacing exhibited slight increase in bulk density and particle density and decrease in porosity of soil, but the difference was non-significant (Table 3). The effect of NPK levels on bulk density, particle density and porosity of soil were also non-significant, although, there was slight decrease in bulk density

Table 2. Effect of NPK and spacing fresh weight and dry weight of plant

Treatment	Fresh weight (kg plant^{-1})			Dry weight (g plant^{-1})		
	2004-05	2004-05	Mean	2004-05	2004-05	Mean
Spacing						
S_1 - 75 x 60 cm	1.74	1.71	1.73	232.53	223.76	228.15
S_2 - 75 x 75cm	1.91	1.87	1.89	264.19	259.24	261.72
S_3 - 90 x 75 cm	2.16	2.04	2.10	298.87	290.40	294.64
SEd	0.08	0.07	-	12.90	11.23	-
CD 0.05	0.21	0.15	-	31.56	27.47	-
NPK Levels (kg ha^{-1})						
F_0 - control	1.43	1.32	1.38	190.02	180.64	185.33
F_1 - 60:40:40	1.84	1.75	1.80	266.13	262.34	264.24
F_2 - 80:60:60	2.17	2.11	2.14	288.35	284.74	286.55
F_3 - 100:80:80	2.32	2.26	2.29	316.29	303.49	309.89
SEd	0.10	0.08	-	14.68	12.75	-
CD 0.05	0.20	0.15	-	30.12	26.16	-

Table 3. Bulk density particle density and porosity of soil at different levels of spacing and NPK fertilizers treatment

Treatment	Bulk density (g cm^{-3})		Particle density (g cm^{-3})		Porosity (%)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Spacing						
S_1 - 75 x 60 cm	1.34	1.35	2.56	2.55	47.05	46.92
S_2 - 75 x 75cm	1.36	1.36	2.56	2.56	46.97	46.38
S_3 - 90 x 75 cm	1.37	1.38	2.57	2.56	46.63	46.10
SEd	0.035	0.027	0.062	0.057	0.73	0.62
CD 0.05	NS	NS	NS	NS	NS	NS
NPK Levels (kg ha^{-1})						
F_0 - control	1.38	1.38	2.58	2.58	46.13	45.67
F_1 - 60:40:40	1.37	1.38	2.55	2.56	45.80	45.83
F_2 - 80:60:60	1.35	1.36	2.56	2.54	47.19	46.52
F_3 - 100:80:80	1.32	1.33	2.55	2.54	48.42	47.83
SEd	0.04	0.31	0.08	0.08	1.01	0.85
CD 0.05	NS	NS	NS	NS	NS	NS

and particle density and increase in porosity with increased lavels of NPK fertilizers (Table 3). It is also evident from data presented in Table 4 that closer plant spacing and increased levels of NPK levels, although, slightly decreased soil pH and electrical conductivity, and increased organic carbon content in soil, the effect was statistically non-significant. Similarly, the effect of NPK levels on pH and electrical conductivity and organic carbon content of soil was also non-significant (Table 4).

Table 5 represents data on per cent increase (+)/decrease (-) of available nutrients of experimental soil over initial value as affected by cape goose berry cultivation under varying levels of

Table 5. Per cent increase (+)/ decrease (-) of available nutrients of experimental soil over initial status under varying levels of plant spacing and NPK fertilizers

Treatment	Per cent increase (+)/ decrease (-) of available nutrients of experimental soil over initial value		
	Nitrogen	Phosphorus	Potassium
Spacing			
S_1 - 75 x 60 cm	(-)6.02	(-)7.73	(-)4.43
S_2 - 75 x 75cm	(-)2.20	(+)0.67	(-)1.34
S_3 - 90 x 75 cm	(+)1.26	(+)4.47	(+)1.73
NPK Levels (kg ha^{-1})			
F_0 - Control	(-)14.56	(-)36.45	(-)13.40
F_1 - 60:40:40	(-)3.57	(-)2.24	(-)1.24
F_2 - 80:60:60	(+)0.967	(+)8.68	(+)1.49
F_3 - 100:80:80	(+)7.87	(+)26.54	(+)7.76

plant spacing and NPK fertilizers. While comparing the nutrient status of soil before and after experimentation under different plant spacing, the results indicated depletion in available nitrogen, phosphorus and potassium of the experimental soil those received the closest plant spacing (75 x 60 cm). There was 6.02, 7.73, 4.43 % depletion in available nitrogen, phosphorus and potassium, respectively under 75 x 60 cm plant spacing while amount of these nutrients were increased by 1.26, 4.47 and 1.73 % under widest plant spacing (90 x 75 cm) over initial values (Table 5). Further, analyzing the available N, P and K in soil due to varying plant spacing treatments, highest amount of available nitrogen in soil was recorded with widest plant spacing (90 x 75 cm) which was significantly superior over the values achieved with medium (75 x 75 cm) and closest (75 x 60 cm) plant spacing (Fig. 2). Similarly, available phosphorus and potassium of experimental soil was also significantly highest with 90 x 75 cm followed by 75 x 75 cm and 75 x 60 cm (Fig. 2).

Fertility status of soil after cape gooseberry cultivation over two cropping season under different NPK fertilizer treatments was found affected (Table 5). The control treatment exhibited 14.56, 36.45 and 13.4 % depletion of available nitrogen, phosphorus and potassium in soil, respectively. There was also depletion in available NPK with F_1 (60:40:40 kg NPK ha^{-1}) treatment where extent of nutrient depletion was noted as 3.57, 2.24, 1.24 % with respect to available nitrogen, phosphorus and potassium, respectively. Contrary to this, cape gooseberry cultivation with the application of 80:60:60 kg NPK ha^{-1} or more resulted in improvement of fertility status of the soil over
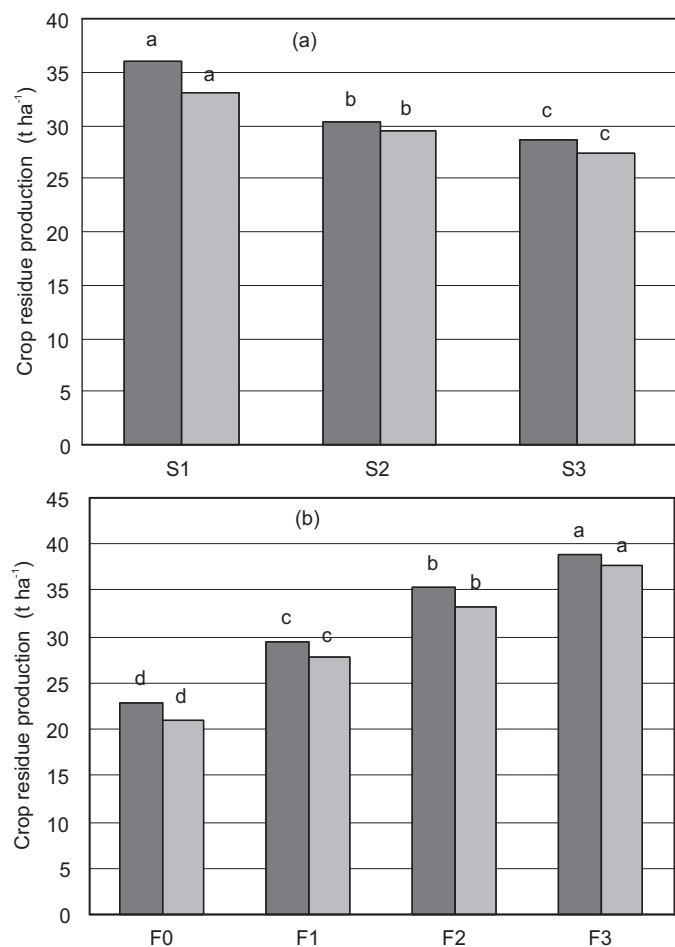

Fig. 1. Crop residue production of cape gooseberry crop at different levels of plant spacing (a) and NPK fertilizers (b). *Bars with different letters within same year in a chart differ significantly at P(0.05). **Spacing: S1=75 x 60 cm S2=75 x 75 cm and S3=90 x 75 cm. ***NPK levels in kg ha-1: F0=control, F1= 60:40:40, F2=80:60:60 and F3=100:80:80.

Table 4. Soil pH, electrical conductivity and organic carbon content of soil under different levels of spacing and NPK fertilizers treatment

Treatment	pH		Electrical Conductivity (dSm^{-1})		Organic carbon (%)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Spacing						
S_1 - 75 x 60 cm	8.28	8.25	0.40	0.38	0.37	0.37
S_2 - 75 x 75cm	8.33	8.28	0.41	0.40	0.36	0.36
S_3 - 90 x 75 cm	8.37	8.36	0.42	0.41	0.35	0.36
SEd	0.16	0.16	0.01	0.01	0.01	0.01
CD 0.05	NS	NS	NS	NS	NS	NS
NPK Levels (kg ha^{-1})						
F_0 - control	8.53	8.46	0.42	0.41	0.34	0.34
F_1 - 60:40:40	8.34	8.30	0.41	0.40	0.36	0.36
F_2 - 80:60:60	8.25	8.22	0.40	0.39	0.36	0.37
F_3 - 100:80:80	8.20	8.16	0.38	0.37	0.38	0.38
SEd	0.23	0.22	0.01	0.01	0.01	0.01
CD 0.05	NS	NS	NS	NS	NS	NS

initial value in terms of increased available nitrogen, phosphorus and potassium. Increase in available nitrogen, phosphorus and potassium of experimental soil with 100:80:80 kg NPK ha^{-1} was 7.872, 6.54, 7.76 %, respectively, while with 80:60:60 kg NPK ha^{-1}, the increase was 0.967, 8.68 and 1.49 %, respectively.

Further, application of each increased levels of NPK fertilizers significantly increased the available nitrogen, phosphorus and potassium of soil (Fig. 2). Highest amount of available nitrogen (205.43 kg ha^{-1}) was recorded with the application of 100:80:80 kg NPK ha^{-1} which was significantly superior over the values
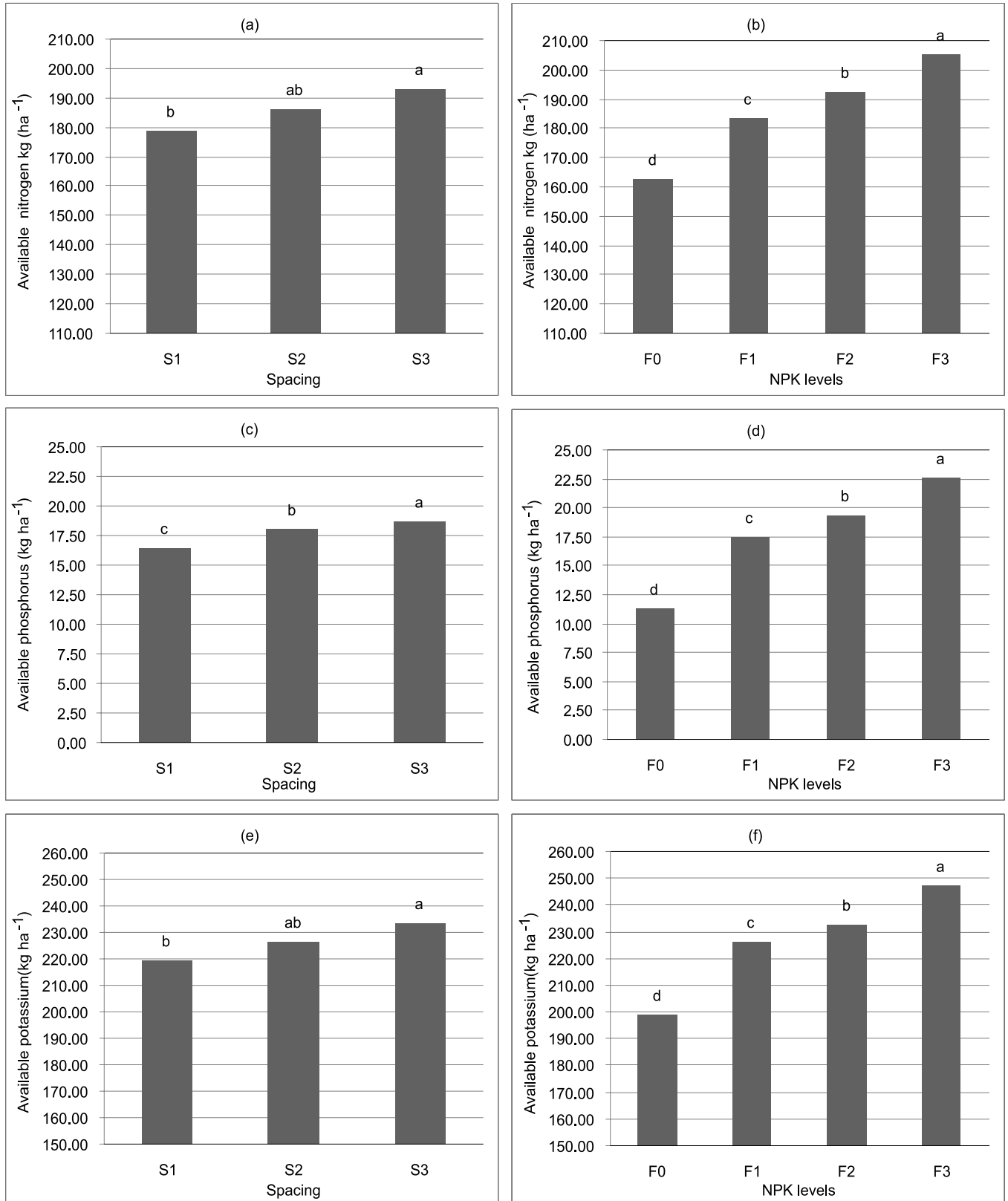

Fig. 2. Available nutrients (nitrogen, phosphorus and potassium) of experimental soil after two years cropping of cape gooseberry at varying levels of plant spacing (a, c and e) and NPK fertilizers (b, d and f). *Initial values of available nitrogen, phosphorus and potassium was 190.44, 17.86 and 229.34 kg ha-1, repectively. **Bars with different letters within same chart differed significantly at P(0.05). ***Spacing: S1=75 x 60 cm, S2=75 x 75cm and S3=90 x 75 cm. ****NPK levels in kg ha-1: F0=Control, F1=60:40:40, F2=80:60:60 and F3=100:80:80.

achieved with 80:60:60 kg NPK ha^{-1} (192.29 kg ha^{-1}), 60:40:40 kg NPK ha^{-1} (183.66 kg ha^{-1}) and control (162.72 kg ha^{-1}). Similarly, available phosphorus and potassium of experimental soil was also significantly highest with 100:80:80 kg NPK ha^{-1} followed by 80:60:60 kg NPK ha^{-1} and 60:40:40 kg NPK ha^{-1}.

The growth of crop is influenced by various factors like climate, soil fertility, growing methods *etc*., among them, the soil fertility and plant spacing are of immense importance and these factors are more responsible for realizing the higher crop growth and biomass production. The spacing or plant population per unit area play decisive role with regards growth of plant. Plants grown at very closer spacing may cause overcrowding and affect the growth of plant while wider spacing could provide enough space to the plant for its potential growth. The higher fresh weight of cape gooseberry plants at wider spacing might be due to more availability of space, less crop competition as well as more availability of plant nutrients which exhibited vigorous plant growth and higher biomass production.

Improvement in physico-chemical properties of soil, more importantly the available nutrients might be attributed to presence of more crop residue in soil under high plant density and increased levels of NPK fertilizers. This emphasizes upon adequate management of crop residues which has significant role in maintenance of soil physical and chemical properties. According to Smith *et al*. (1992) crop residues improve soil organic matter dynamics and nutrient cycling, thereby creating a most efficient system. Karchoo and Dixit (2005) emphasized that incorporation of crop residues not only improved crop yield but also increased nutrient uptake besides improving the physicochemical and biological properties of the soil, providing a better soil environment for growth and development. Recycling of crop residues has been suggested to improve over all soil conditions and to support sustainable rice production and the benefits of incorporating un-decomposed straw are recognised in tropical environments (Flinn and Marciano 1984; Bhardwaj and Gaur, 1985).

The study revealed that crop residue (fresh biomass) production is inflenced by plant spacing and application of NPK fertilizers. Increased plant population per unit area as well as higher doses of NPK levels showed a little improvement in bulk density, porosity, organic carbon, pH and EC of soil but influence was non-significant. Plant spacing and NPK fertilizer treatments exhibited significant improvement in available nitrogen, phosphorus and potassium of the soil at the end of the second cropping season.

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