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OPTIMIZING POTATO PRODUCTIVITY IN FOOD GRAIN-BASED ORGANIC FARMING SYSTEM UNDER SPRINKLER IRRIGATION

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ABSTRACT: Field trials were carried during 2013-16 in randomized block design for groundnut-potato-maize+greengram system consisting seven organic input treatment combinations. For crop raising, regional recommendations were adopted, and their nutritional requirement in various organic treatments was calculated as per their recommended inorganic doses. Cultural weed control was followed, and disease-pest management was done through permitted organic means. Observations of growth, yield attributes and yield were recorded for all component crops of the system. Process grade tuber yield improved from 10.5 t/ha to 18.5 t/ha, while total tuber yield increased from 59.9% to 88.3% from first to third year. Tuber weight loss (18.8%) reduced drastically in organic system (IA) over inorganic nutrition (24.5%) at 90 days under ambient storage conditions. System productivity of organic system (IA) improved to 91.3% of inorganic nutrition in third year. Organic system (IA) observed lower net returns in first year, while improvement was observed in third year as this gap reduced to 16.7%. This study suggests that sustainable potato yields can be harnessed in food grain-based cropping systems by including leguminous crops and integrating different organic nutrient sources.

KEYWORDS: Potato, Organic farming, Maize, Green gram, Groundnut, System productivity

INTRODUCTION

Organic farming has gained considerable attention and has emerged as a dynamic 'Alternate Farming System'. Its principal objective is quality food production for humans and animals while maintaining ecological and economic viability. Safety, protection, and conservation of environment are the need of hour and organic cultivation practices ensure this. It is also becoming popular in domestic and international markets as consumers are becoming more serious about food quality, especially chemical residues. This awareness and demand for quality food have created new market opportunities for farmers with premium selling prices and potato is no exception to all these trends and market avenues.

Potato is a significant diet component at the national level as it is consumed fresh and processed in numerous ways. Globally, India is the second-largest potato producer and the second advance estimate of 2020-21 has estimated total production of 53.7 mt from a 2.25 mha area with approximately 2.4 t/ha of average yield (Anon, 2021). North Indian plains contribution is around 87% in total national potato production. Current crop scenario in India suggests its diversified production and utilization in the domestic and export market, and organic potatoes can be one alternative. In addition, higher profits can be earned in domestic and international markets through organic potato production.

Adopting intercropping or sequential cropping and efficient irrigation system helps in efficient utilization of precious resources, *viz.*, land, water, and nutrition. Further, integration of nutrient management options for a cropping systems may economise the

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crop's nutrition requirement effectively. To meet the future challenges of increasing food demand while simultaneously decreasing its negative impact on the environment, efforts should be on for increasing the efficiency of both conventional and organic production systems (Pawelzik *et al*., 2014). Nelson *et al*. (2009) have suggested that extended rotations used in organic potato production systems retain soil organic matter and allow recovery of crucial attributes of soil following the potato phase. With this background, field experiments have been conducted for optimizing the potato productivity under food grain-based organic farming systems.

MATERIALS AND METHODS

A field experiment was conducted on fixed plots at ICAR- Central Potato Research Institute Regional Station, Modipuram (29° 05'19'' N, 77° 41'50'' E, 237 m asl) under semi-arid and sub-tropical agro-ecology during 2013-16. The soil of experimental site was sandy loam in texture with neutral pH, and was low in organic carbon content and available nitrogen, while available phosphorus and potassium was in medium range. Crop rotation of groundnut- potato- maize+ Green gram in replicated randomized block design was followed. Treatments (7) consisted of T_1- control; T_2 - Conventional system; T_3- Organic system of crop residue recycling (CRR); T_4- Organic system of bio-fertilizers and microbial application (BM); T_5- Organic system of organic manures incorporation (OM); T_6- Organic system with homeopathic approach (HO) and T_7- Organic system with all combinations of source of nutrition excepting homeopathic products (IA). Potato planting was done in the last week of October and haulms cutting was done at 110 days for Kufri Himsona. Water application was made at 125% CPE level through the sprinkler system. Harvesting was done 10 days later, where grading was done manually and a tuber of >45 mm was considered marketable for cv. K. Himsona (processing size). Succeeding crops, i.e., Maize (Pahuja hybrid Kanchan) & Green gram (Pahuja cv. Nirali/ Sudha) in 1:1 inter-cropping were raised during March- June by following the recommended package of practices. Likewise, Groundnut (BARC cv. TG37A) was grown during July- October by adopting standard practices. Nutrient management under various treatments is given in Table 1. Observations of emergence, growth, yield attributes and yield were recorded as per the schedule of the technical program for all component crops of this system. The data was compiled and analysed using statistical software IRRISTAT (IRRISTAT, 1999).

RESULTS AND DISCUSSION

Potato

Growth and physiological parameters: Pooled analysis of three years revealed that plant height (cm) and Leaf area Index (LAI) varied significantly, while shoot number/ plant, compound leaf number/ plant, and chlorophyll content (SPAD values) did not have any significant differences **(Table 2)**. Maximum plant height (55.9), leaf no. (52.3), chlorophyll content (48.4) and LAI (3.06) were recorded in inorganic treatment, whereas organic system (IA) tended to have better plant height (43.8), leaf no. (45.5), chlorophyll content (40.8) and LAI (2.35). Fresh and dry leaf and stem weight (gram) at 60 days differed significantly, and inorganic nutrition observed the highest of these traits. But tuber fresh and dry weight remained at par. Inorganic nutriton had fresh leaf (200.9), stem (115.6) and tuber (273.2) weight and organic system (IA) achieved fresh leaf (110.5), stem (56.1) and tuber (200.0) weight. Dry matter weight followed a similar trend. Crop performance in initial establishment of

Table 1: Treatment details for nutrient management (doses and method of application)

Nutrient management	Groundnut	Potato (Processing purpose)	Maize+ *moong* bean
T_1- Control (No nutrient application)	-	-	-
T_2- Conventional system (Inorganic)	25 N-50 P_2O_5-50 K_2O kg/ha; Band placement	270 N-80 P_2O_5-150 K_2O kg/ha; Band placement and broadcasting	150 N-80 P_2O_5-80 K_2O kg/ha; Band placement and broadcasting
T_3- Organic system (Crop residue recycling of preceding crop within the plot)	Maize+ *moong* bean Stover: Approx. 15-19 t/ha; *in situ* incorporation	Groundnut Stover: Approx. 5-10 t/ha; *in situ* incorporation	Potato haulms: Approx. 4-7 t/ha; *in situ* incorporation
T_4- Organic system* (Biofertiliser/ microbial formulation)	*Rhizobium, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM	*Azotobacter, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM	*Azotobacter, Rhizobium, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM
T_5- Organic system (Organic manure: One-third of each: FYM, compost, vermicompost on nitrogen content basis)	FYM (2 t/ha)+ compost (2 t/ha)+ vermi-compost (1 t/ha); FYM & compost before sowing, vermi-compost at sowing	FYM (15 t/ha)+ compost (33 t/ha)+ vermi-compost (6 t/ha); FYM & compost before planting, vermi-compost at earthing	FYM (6 t/ha)+ compost (21 t/ha)+ vermi-compost (3 t/ha); FYM & compost before sowing, vermi-compost at 30-35 days
T_6- Organic system* (Homeopathic approach)	FYM (5 t/ha)+ Homeo products	FYM (5 t/ha)+ Homeo products	FYM (5 t/ha)+ Homeo products
T_7- Organic system (Integrated Approach except homeopathic products)	Maize+ *moong* bean Stover: Approx. 15-19 t/ha; *in situ* incorporation + *Rhizobium, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM + FYM (2 t/ha)+ vermi-compost (1 t/ha); FYM before sowing, vermi-compost at sowing	Groundnut Stover: Approx. 5-10 t/ha; *in situ* incorporation + *Azotobacter, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM+ FYM (15 t/ha)+ vermi-compost (6 t/ha); FYM before planting, vermi-compost at earthing	Potato haulms: Approx. 4-7 t/ha; *in situ* incorporation + *Azotobacter, Rhizobium, Bacillus subtilis, Trichoderma*; seed treatment & mixed with FYM+ FYM (6 t/ha)+ vermi-compost (3 t/ha); FYM before sowing, vermi-compost at 30-35 days

*Organic system (Biofertiliser/ microbial formulation): *Rhizobium* (250g/ha seed treatment), *Bacillus subtilis* (250g/ha seed treatment), *Azotobacter* (250g/ha seed treatment), *Trichoderma* (4 kg/ha with 100 kg FYM for mixing in soil)

*Organic system (Homeopathic approach): Organic home products used as per the literature given on the website:
Sanjeevani: Soil treatment @ 1.3 L+ 5 kg jaggary+ 4q FYM/ ha and three spray @ 2.5 L+ 10 kg jaggery in 500 L water per ha for nitrogen (groundnut, potato, maize+ *moong* bean)
Amrit: Seed treatment @ 2 L+ 4kg jaggary+ water/ ha for phosphorous and potassium (groundnut, potato, maize+ *moong* bean)
Rakshak: Three sprays @ 2.5 L+ 10 kg jaggery in 500 L water per ha for diseases (potato)
Jeevan: Three sprays @ 2.5 L+ 10 kg jaggery in 500 L water per ha for diseases (groundnut, potato, maize+ *moong* bean)
Vardaan: Three sprays @ 2.5 L+ 10 kg jaggery in 500 L water per ha for diseases (groundnut)
Moksha: Two/ three spray @ 2.5 L in 500 L water per ha for pests (groundnut, potato, maize+ *moong* bean)

organic farming is a challenge and growth suffers due to lower nutritional supply particularly nitrogen (Finckh *et al*., 2006).

Graded tuber number and yield: Process grade and total tuber yield (t/ha) varied statistically with variations in source of nutrition **(Fig. 1)**. Lower tuber bulking adversely affected graded and total tuber yield in organic treatments. In first crop season, conventional system attained highest process grade (26.8) and total (44.2) tuber yield, which was distinctly higher over all other treatments. Organic system (IA) had process grade (10.8) and total (26.5) tuber yield, which was respectively, 59.7 and 40.0% lower over conventional system. During second year again, maximum and statistically better process (22.1) and total tuber yield (25.6) was recorded in conventional system. Organic system (IA) had process (18.5) and total tuber yield (22.6), and this treatment could maintain 83.7 and 88.3% of tuber yields, respectively, in comparison to inorganic system. In third season also, highest and significantly better process (22.6) and total tuber yield (28.0) was attained by inorganic treatment. Organic

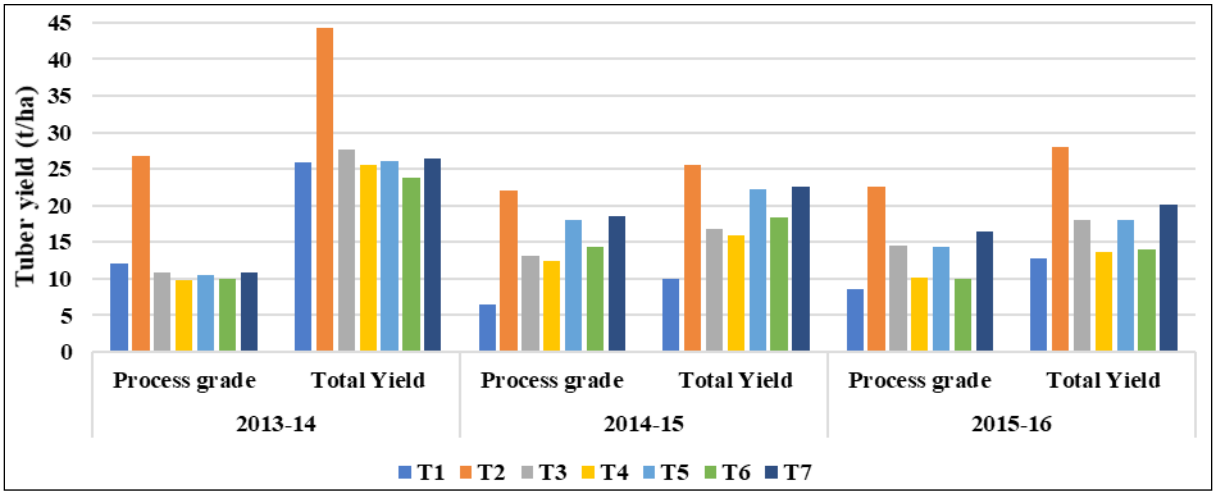

Fig 1: Yield performance of Kufri Himsona under conventional and organic systems

Table 2: Influence of nutrient management options on plant growth and physiological traits of potato

Treatments	Plant height (cm)	Shoot no./ plant	Leaf no./ plant	Chlorophyll content	Leaf area index	Leaf weight (g)*		Stem weight (g)*		Tuber weight (g)*	
						Fresh	Dry	Fresh	Dry	Fresh	Dry
T_1	32.8	4.69	35.6	39.1	1.70	84.6	10.6	35.6	3.18	179.0	43.4
T_2	55.9	4.69	52.3	48.4	3.06	200.9	21.5	115.6	8.61	273.2	55.8
T_3	40.3	5.56	42.6	40.5	2.12	108.3	11.9	53.4	4.57	209.6	52.5
T_4	39.4	5.15	37.9	40.4	1.81	97.4	11.6	41.2	3.37	228.5	55.6
T_5	42.2	5.05	39.3	41.6	2.17	100.2	10.8	52.9	4.37	227.1	52.3
T_6	39.2	5.40	40.4	38.8	1.94	89.9	9.8	47.1	3.77	204.3	48.2
T_7	43.8	4.50	45.5	40.8	2.35	110.5	12.5	56.1	5.23	200.0	46.0
CD 0.05	10.48	NS	NS	NS	0.54	30.60	3.99	16.4	1.61	NS	NS

*At 60 days of growth

system (IA) recorded process (16.5) and total tuber yield (20.2). It was highest among organic systems and statistically better over organic system (BM) and organic system (HO). This treatment maintained 73.0 and 72.1% of process and total tuber yields, respectively as compared to inorganic nutrition. Singh *et al.* (2006) observed maximum tuber yield and net return from 30 t/ha with FYM application and recommended application of N, P and K. Hagman *et al.* (2009), in their experimental results, implied the timing of N application is essential for yield and concluded that the importance of P and K fertilization is underestimated in organic production and that the most crucial cultivar trait in achieving acceptable yield is long-lasting foliage, a characteristic of resistannce to *Phytophthora infestans*. Economic and biomass yield revealed that harvest index (HI) was similar in all organic treatments (**Table 3**). Inorganic nutrition recorded HI of 0.84, while organic system (IA) had a harvest index of 0.91. Green manure at higher rates (400 and 200 Kg/ha) increased the accumulation of dry matter in potato aboveground parts and tubers observed by Mohamed *et al.* (2017).

Tuber quality and storability: Tuber dry matter content (TDMC in %), specific gravity (SG), reducing sugars (mg/ 100g fresh tuber

Table 3: Influence of nutrient management options on quality traits, biomass yield and storability

Treatment	Tuber dry matter content	Specific gravity	*Reducing sugars (mg)	**Chip colour score	Haulms		Tuber		Biomass yield (t/ha)#	Harvest index#	Total weight loss (%) at 30 days interval		
					Fresh	Dry	Fresh	Dry			30	60	90
T_1	22.2	1.094	34.4	2.7	2.47	0.28	16.2	3.60	3.88	0.93	4.6	8.1	17.5
T_2	21.3	1.089	43.3	2.9	13.23	1.37	32.6	6.95	8.32	0.84	6.1	17.5	24.5
T_3	22.1	1.091	28.3	2.6	4.92	0.51	20.8	4.60	5.11	0.90	6.0	11.9	19.8
T_4	22.3	1.093	28.1	2.7	3.45	0.36	18.4	4.11	4.47	0.92	5.6	10.5	18.0
T_5	22.0	1.093	27.6	2.5	4.65	0.50	22.1	4.87	5.37	0.91	8.1	11.5	20.0
T_6	22.6	1.093	33.2	2.6	3.13	0.34	18.7	4.23	4.57	0.93	4.7	10.2	18.1
T_7	22.3	1.092	32.0	2.7	4.69	0.51	23.1	5.14	5.65	0.91	4.7	10.2	18.8
CD 0.05	0.5	NS	3.12	NS	0.81	0.08	5.24	0.67	1.04	-	1.42	2.85	4.88

*mg/100g Fresh tuber weight; **Chip colour score: 1-9 where up to 3 the product is in an acceptable range; #dry weight basis

weight) and chip colour score (on 1- 10, acceptable up to 3) improved significantly in organic nutrition **(Table 3)**. Lombardo *et al.* (2012) reported organic farming to produce potatoes with a higher nutritional value due to higher total phenolic and lower nitrate content and better sensory performance after frying (strong taste and crisp flesh). The highest TDMC (22.26) & SG (1.092) and lowest reducing sugars (32.0) & chip colour (2.7) were found in the organic system (IA), whereas inorganic treatment had TDMC (21.32), SG (1.089), reducing sugars (43.3) and chip colour (2.9). Similar observations were reported by Bandana *et al.* (2018) while studying the source of nutrition on potato tuber quality under elevated storage conditions. Organic treatments had better storability than inorganic treatments (Bandana *et al.*, 2018). Minimum total weight loss was observed in the organic system (BM) at ninety days (18.0%), whereas inorganic nutrition had the highest losses (24.5%). Organic system (IA) recorded 18.8% weight loss at 90 days. The same observations were reported by El-Sayed *et al.* (2015).

Maize

Growth and physiological parameters: Germination of Maize and plant population (>90%) were not influenced due to different treatments **(Table 4)**. Plant height (cm)

Table 4: Influence of nutrient management options on growth and yield performance of Maize

Treatment	Plant height (cm)		Chlorophyll content		Leaf area index		Cob number (000/ha)		Grain yield (t/ha)		Straw yield (t/ha)		Biomass (t/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	1.69	1.22	45.9	33.9	3.47	1.41	52.2	51.8	3.7	1.9	13.7	13.9	21.4	15.8
T_2	1.74	1.32	55.2	45.4	4	2.27	58.2	70.1	5	3.9	18.1	18.2	26.9	22.1
T_3	1.73	1.32	46.2	38.1	3.65	2.29	53.3	58.1	4.33	2.7	13.2	14.9	21.6	17.6
T_4	1.69	1.21	46.7	37.1	3.75	2.04	52.5	55.6	4.25	2.6	13.2	13.8	21.3	16.4
T_5	1.73	1.25	51.2	42.7	3.92	1.95	53.8	66.9	4.33	3.1	14.2	15.5	22.1	18.6
T_6	1.69	1.27	43.5	38.5	4	2.07	52.7	63.1	4.31	3.5	13.1	15.4	21.2	18.9
T_7	1.72	1.37	49.1	41.3	3.95	2.25	53.8	67.6	4.35	3.6	15.7	17.7	24	21.3
$CD_{0.05}$	NS	NS	2.59	3.26	0.27	0.39	3.1	3.1	0.51	0.63	2.09	1.72	2.67	2.52

also remained statistically similar with different nutritional sources. However, in both years, LAI and chlorophyll content exhibited significant differences. In the first season, the organic system (IA) recorded comparable plant height (172.5) to inorganic nutrition (174.1). This treatment attained a similar LAI (3.95) to the conventional system (4.00). Whereas maximum chlorophyll content (SPAD values) was observed with inorganic source (55.2), which was distinctly higher than overall organic treatments, and organic system (IA) attained SPAD value of 49.1. Alike, organic system (IA) recorded comparable LAI (2.25) to organic system CRR (2.29) and inorganic nutrition (2.27) in the second crop season. On the other hand, maximum chlorophyll content was recorded with an inorganic source (45.4), which was significantly higher than overall organic treatments and the organic system (IA) attained a SPAD value of 41.3. Bilalis and Karamanos (2010) also reported comparable growth of maize crop in conventional and organic treatments in organic experiments.

Yield attributes and yield: The clear-cut difference was visible in yield attributes, i.e., cob number (000/ha), grain, straw, and biomass yield (t/ha) with inorganic and organic nutrition **(Table 4)**. During 2013-14, Inorganic sources attained maximum and statistically superior cob no. (58.2), grain (5.00), straw (18.1) and biomass yield (26.9) over other treatments. Organic system (IA) remained the second-best option and it had cob no. (53.8), grain (4.35), straw (15.7) and biomass yield (24.0). This treatment could achieve 87% grain productivity compared to the inorganic system. Similarly, inorganic sources attained maximum cob no. (70.1), grain (3.9), straw (18.2) and biomass yield (22.1) during 2014-15, which was statistically better over several other treatments. Organic system (IA) remained second best and had cob no. (67.6), grain (3.6), straw (17.7) and biomass yield (21.3). This treatment achieved 92.3% grain yield over an inorganic system. Bilalis and Karamanos (2010) also concluded that sustainable yield of maize is possible in organic agriculture systems.

Green gram

Growth and physiological parameters: Green gram attained normal germination and plant stand (>90%) in both years **(Table 5)**. Plant height showed statistically significant differences in the first season. The highest plant height (64.9 cm) was attained by the organic system (IA), which was significantly better over inorganic, organic (CRR), and organic (BM) treatments. Chlorophyll content did not exhibit any significant differences and organic system (IA) recorded a SPAD value of 58.2, similar to inorganic nutrition (60.5). While in second year, plant height and chlorophyll content remained at par in all treatments. The highest plant height (36.2 cm) and SPAD value (66.3) was recorded in the organic system (BM), while organic (IA) had plant height (34.6) and SPAD value (63.7). Acharya and Mondal (2010) also reported that Green gram performed alike in inorganic and organic treatments.

Yield attributes and yield: In the first year, yield attributes and yield were not influenced by variation in plant nutrition in component crop Green gram **(Table 5)**. Organic system (IA) recorded comparable pod (0.36), grain (0.23), straw (1.8) and biomass yield (2.2). Yield attributes and yield were affected significantly by nutrition sources during 2014-15. The organic system (BM) observed the highest grain (0.44) and biomass yield (3.4), remaining statistically better over several treatments. The organic system (IA) had a comparable pod (0.35) and lower biomass yield (2.6). Inorganic nutrition, higher Maize Equivalent Yield (MEY) 5.14 was observed

Table 5: Influence of nutrient management options on growth and yield performance of Green gram

Treatment	Plant height (cm)		Chlorophyll content		Pod yield (t/ ha)		Grain yield (t/ ha)		Straw yield (t/ha)		Biomass (t/ha)		Maize equivalent yield (t/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	49.6	33.7	55.5	63.8	0.34	0.42	0.22	0.24	1.7	1.7	2	2.12	4.45	2.81
T_2	60	34.9	60.5	64.5	0.42	0.52	0.23	0.33	1.7	2.1	2.1	2.62	5.79	5.16
T_3	60.1	35.9	58.4	65.2	0.37	0.65	0.23	0.39	1.7	2.3	2.1	2.95	5.12	4.19
T_4	60.8	36.2	58.2	66.3	0.39	0.7	0.25	0.44	1.7	2.7	2.1	3.4	5.11	4.28
T_5	63.4	34	60.7	63.4	0.34	0.59	0.21	0.34	1.7	2.1	2	2.69	5.05	4.4
T_6	65.4	34.2	58.1	64	0.36	0.53	0.22	0.31	1.8	1.9	2.2	2.43	5.06	4.68
T_7	64.9	34.6	58.2	63.7	0.36	0.6	0.23	0.35	1.8	2	2.2	2.6	5.14	4.94
$CD_{0.05}$	4.77	NS	NS	NS	NS	0.11	NS	0.08	NS	0.4	NS	0.51	-	-

in the organic system (IA), which was 88.8% of the productivity of inorganic nutrition (5.79) in the first year. Similarly, the highest MEY (4.94) was in this system and 95.7% of inorganic treatment (5.16). Productivity of Green gram was similar in inorganic and organic plots and was not affected by lower N supply due to symbiotic N- fixation (Acharya and Mondal, 2010).

Groundnut

Growth and physiological parameters: Groundnut had normal germination and plant stand (>90%) in all treatments in both years **(Table 6)**. Growth and physiological parameters *viz.*, plant height (cm) and LAI depicted significant differences during 2013-14. Organic system (IA) recorded comparable plant height (22.8) to inorganic nutrition (22.4) and most of the organic sources. Maximum LAI (1.90) was observed in the organic system (CRR), which was statistically at par with the organic system (IA) and inorganic source having values of 1.52 and 1.87, respectively. Chlorophyll content (SPAD values) did not vary statistically among all treatments, and organic system (IA) recorded a value of 37.6 like inorganic treatment (36.6). Growth and physiological parameters viz., plant height (cm), LAI and chlorophyll content did not differ significantly due to source of nutrition during 2014-15. Organic

Table 6: Influence of nutrient management options on growth and yield performance of Groundnut

Treatment	Plant height (cm)		Leaf area index		Chlorophyll content		Pod yield (t/ ha)		Grain yield (t/ha)		Straw yield (t/ha10		Biomass yield (t/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	19.3	22.9	1.71	2.13	37.4	37.1	0.78	0.53	0.57	5.33	5	5.86	5.6	5.86
T_2	22.4	21.8	1.87	2.22	36.6	37.7	0.81	0.54	0.59	5.8	5.4	6.34	6.1	6.34
T_3	22.8	20.4	1.9	2.23	36.1	36.2	0.76	0.53	0.55	5.4	5.1	5.93	5.8	5.93
T_4	20.5	22.1	1.39	2.24	38.4	35.9	0.8	0.57	0.58	5.12	4.9	5.69	5.6	5.69
T_5	22.8	20.8	1.57	1.96	38.1	35.8	0.73	0.52	0.53	5.17	5	5.69	5.6	5.69
T_6	23	20.8	1.39	2.09	37.5	37.5	0.76	0.51	0.55	5.53	5	6.04	5.7	6.04
T_7	22.8	21.8	1.52	2.29	37.6	36.7	0.81	0.53	0.59	5.79	5	6.32	5.8	6.32
$CD_{0.05}$	2.2	NS	0.39	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

system (IA) recorded plant height (21.8), LAI (2.29) and chlorophyll content (36.7). In trial of Basu *et al*. (2008), Groundnut attained similar growth traits in organic nutrition as with inorganic fertilizers.

Yield attributes and yield: In both crop seasons, pod, grain, straw and biomass yield (t/ha) were not affected significantly by a different source of nutrition in Groundnut **(Table 6)**. Organic system (IA) recorded comparable pod (0.81), grain (0.59), straw (5.0) and biomass yield (5.8) to inorganic nutrition. A similar trend was observed in second year. Organic system (IA) observed grain (0.53), straw (5.79) and biomass yield (6.32), which were comparable to inorganic treatment. Yield attributes and yield of Groundnut crop were found to be comparable in organic and inorganic treatments (Basu *et al*., 2008).

System productivity and economics: System productivity of Potato- Maize+ Green gram-Groundnut rotation was computed based upon support price fixed by the government for cereals and the prevailing market price of potatoes during harvest time **(Table 7)**. In the first year, organic system (IA), organic system (OM) and organic system (HO) recorded 56.6, 55.5 and 47.8 t/ha system productivity, respectively, which was 89.0, 87.3 and 75.2% of the inorganic treatment productivity (63.6 t/ha). Alike, inorganic nutrition had 16.7 and 11.6-16.0 % higher net return and B: C ratio over best organic system (OM) and organic system (IA). As a result, the organic system (IA) had 35.7 t/ha system productivity in the second year, 91.3% of the inorganic treatment (39.1 t/ha). On the other hand, inorganic nutrition had a 21.3 and 21.5 % higher net return and B: C ratio over the best organic system (IA). Wachter *et al*. (2019) studied productivity, economics and soil quality parameters in conventional, mixed and organic dryland farming systems in eastern Washington State. They concluded that productivity of the system stabilizes slowly over the years in organic farming system and becomes sustainable.

CONCLUSION

A sustainable organic farming-based cropping system must be developed to achieve optimum potato yields as this crop requires higher quantity of nutrients for growth and productivity. Yield maintenance under organic farming (IA) was stable in potato crop in third year in sprinkler irrigation as it attained 73.0% of process grade and 72.1% of total tuber yield in comparison to inorganic treatment. Similarly, organic system (IA) had 35.7 t/ha system productivity, which was

Table 7: Influence of nutrient management options on system productivity and economics of production.

Treatment	*System productivity (t/ha)		Cost of cultivation (Rs/ha)		Gross returns (Rs/ha)		Net returns (Rs/ha)		B: C ratio	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	30.1	19.4	160710	168745	240800	155200	80090	-13545	0.5	-0.08
T_2	63.6	39.1	180807	189847	508800	312800	327993	122953	1.81	0.65
T_3	44.7	28.6	165850	174142	357600	228800	191750	54658	1.16	0.31
T_4	43.0	28.2	165800	174090	344000	225600	178200	51510	1.07	0.3
T_5	55.5	34.4	170800	179340	444000	275200	273200	95860	1.6	0.53
T_6	47.8	30.8	168000	176400	382400	246400	214400	70000	1.28	0.4
T_7	56.6	35.7	179900	188895	452800	285600	272900	96705	1.52	0.51

*Potato equivalent yield (based upon the price of produce and yield)

91.3% of the inorganic treatment (39.1 t/ha). However, inorganic nutrition had 16.7 and 16.0 % higher net return and B: C ratio over organic system (IA).

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LITERATURE CITED

Acharya D and Mondal SS (2010) Effect of integrated nutrient management on the growth, productivity and quality of crops in rice (*Oryza sativa*)- cabbage (*Brassica oleracea*)- green gram (*Vigna radiata*) cropping system. *Indian J Agron*. **55**(1): 1-5

Anonymous (2021) Department of agriculture and farmers welfare, HTTP:// https://agricoop.nic.in/en/statistics/horticulture-crops-2019-20-second-advance-estimates, 20 December 2021

Basu M, Bhadoria PB and Mahapatra SC (2008) Growth, nitrogen fixation, yield and kernel quality of peanut in response to lime, organic and inorganic fertilizer levels. *Bioresource technology* **99**(11): 4675-83

Bilalis DJ and Karamanos AJ (2010) Organic maize growth and mycorrhizal root colonization response to tillage and organic fertilization. *J Sustainable Agriculture* **34**(8): 836-49

El-Sayed SF, Hassan HA and El-Mogy MM (2015) Impact of bio-and organic fertilizers on potato yield, quality and tuber weight loss after harvest. *Potato Research* **58**(1): 67-81

Finckh MR, Schulte-Geldermann E, Bruns C (2006) Challenges to organic potato farming: disease and nutrient management. *Potato Research* 49(1): 27-42

IRRISTAT (1999) Windows version 4.0., Biometrics unit, IRRI, Los Banos, Philippines

Kaundal B, Kumar D, Kumar P, Rawal S, Saini N and Sharma V (2018) Influence of source of nutrition on potato (*Solanum tuberosum*) tuber quality in elevated temperature storage. *Indian J of Agril Sci* 88: 1371-1378

Lombardo S, Pandino G and Mauromicale G (2012) Nutritional and sensory characteristics of "early" potato cultivars under organic and conventional cultivation systems. *Food Chemistry* 133(4): 1249-1254

Mohamed EM, Watthier M, Zanuncio JC and Santos RH (2017) Dry matter accumulation and potato productivity with green manure. *Idesia* **35**(1): 79-86

Nelson KL, Lynch D and Boiteau G (2009) Assessment of changes in soil health throughout organic potato rotation sequences. *Agriculture, ecosystems & environment* **131**(3-4): 220-228

Pawelzik E and Möller K (2014) Sustainable potato production worldwide: the challenge to assess conventional and organic production systems. *Potato Research* **57**(3-4): 273-290

Singh SP and Kushwah VS (2006) Effect of integrated use of organic and inorganic sources of nutrients on potato (*Solanum tuberosum*) production. *Indian J Agron* **51**(3): 236-238

Wachter JM, Painter KM, Carpenter-Boggs LA, Huggins DR and Reganold JP (2019) Productivity, economic performance, and soil quality of conventional, mixed, and organic dryland farming systems in eastern Washington State. *Agriculture, Ecosystems & Environment* **286**: (https://doi.org/10.1016/J.AGEE.2019.106665).

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