



Eliciting Physiological and Biochemical Effects of Agronomic Management in Chinese Potato [*Plectranthus rotundifolius* (Poir) Spreng]

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ABSTRACT

Background: Chinese potato [*Plectranthus rotundifolius* (Poir.) J.K. Morton] also known as coleus is cultivated in many parts of the world for its edible tubers. Despite a high production potential, the productivity of Chinese potato appears to be limited by a lack of balance between the source and sink capacities. The objective of the study was to investigate the effect of agronomic management practices viz., planting methods, nutrient management and growth promoters on physiological and biochemical responses in Chinese potato.

Methods: An investigation was undertaken at College of Agriculture, Vellayani, Thiruvananthapuram during October to February of 2019 - '20 and repeated in 2020 - '21 in split plot design with five methods of planting as main plots (bed/ridge method of planting with 30 cm x 15 cm, 30 cm x 30 cm and mound method of planting with 30 cm x 30 cm spacing) and six combinations of nutrient management practices (60:30:120 kg NPK/ha with and without PGPR Mix 1) and growth promoters (humic acid, benzyl adenine and water spray) as sub-plot treatments replicated four times.

Result: The results revealed the superiority of bed method of planting at 30 cm x 15 cm spacing with the application of 60:30:120 kg NPK ha⁻¹ + PGPR Mix 1 + humic acid (m₁n₁g₁) on physiological attributes viz. DMP, CGR and LAI was found most productive resource management practice in Chinese potato.

Key words: Agronomic, Chinese potato, Growth promoters, Methods of planting, Nutrient, Physiological parameters.

INTRODUCTION

Chinese potato [*Plectranthus rotundifolius* (Poir.) Spreng.], also known as coleus is a minor tuber crop grown for its edible tubers having peculiar aroma and nutritional quality. Its cultivation is often constrained by the small size of tubers that affects marketability, but has huge potential among tuber crops on account of its short duration nature and suitability for inclusion in different sequential cropping systems. The low yields, genetic character, lack of balance between the source potential and sink capacity which can be modulated through agronomic management practices. A high source activity and low sink capacity (temperate climates) and *vice versa* (tropical and subtropical climates) limits the yield. Agronomic management of resources can result in variations in physiological and biochemical responses in crop plants.

Review of earlier studies in tuber crops elucidate the impact of agronomic practices on the growth and physiology of the plants. Singh (2013) adverted that physiological traits varied significantly due to spacing in *Coleus forskohlii* and documented the significant influence of spacing on leaf area, dry matter, LAI (leaf area index), CGR (crop growth rate) and RGR (relative growth rate). Humic acid, a naturally occurring polymeric organic compound produced during decomposition of organic materials, has been illustrated to increase the permeability of plant membranes, N metabolism and chlorophyll content (Haghighi *et al.*, 2012), enhance the uptake of nutrients in

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wheat (El-Bassiouny *et al.*, 2014). Foliar application of PGRs helps to translocate the nutrients from leaves to all parts thereby helps in modulating the source - sink balance (Pooja and Ameena, 2021). Plant growth promoting substances had a positive effect on cell division and cell elongation leading to enhanced leaf expansion (Pooja *et al.*, 2023). Nevertheless, a comprehensive study on the physiological responses of Chinese potato to crop husbandry aspects is meagre. In this backdrop, the present investigation was undertaken to elicit the physiological and biochemical responses in Chinese potato with agronomic management practices in the Southern Laterites of Kerala.

MATERIALS AND METHODS

The experiment was conducted at the Instructional farm, College of Agriculture, Vellayani (8.5°N latitude and 76.9°E

longitude and 29 m above msl), Kerala during November to July of 2019-20 and confirmatory experiment during October to March of 2020-21. The soil before the start of experiment was analysed and was found to be acidic pH (6.05), with medium available N ($301.06 \text{ kg ha}^{-1}$), high available P (27.24 kg ha^{-1}) and available K ($327.04 \text{ kg ha}^{-1}$). The photo-insensitive coleus variety Suphala released from Kerala Agricultural University was used for the study. Field experiment was laid out in split plot design with five methods of planting as main plots and six combinations of nutrient management practices (2) and growth promoters (3) as sub-plot treatments in four replications. The main plot treatment, methods of planting included m_1 : bed method ($30 \text{ cm} \times 15 \text{ cm}$), m_2 : bed method ($30 \text{ cm} \times 30 \text{ cm}$), m_3 : ridge method ($30 \text{ cm} \times 15 \text{ cm}$), m_4 : ridge method ($30 \text{ cm} \times 30 \text{ cm}$) and m_5 : mound method ($30 \text{ cm} \times 30 \text{ cm}$). Nutrient management practices (n_1 : 60:30:120 kg NPK ha^{-1} + PGPR Mix 1, n_2 : 60:30:120 kg NPK ha^{-1}) and growth promoters (g_1 : humic acid @ 5 g l^{-1} , g_2 : benzyl adenine @ 50 mg l^{-1} and g_3 : water spray) in combination comprised the sub-plot treatments. The land was ploughed thoroughly, limed @ 100 kg/ha based on the soil test results and laid out into main ($14.4 \text{ m} \times 1.5 \text{ m}$) and sub-plots ($2.4 \times 1.5 \text{ m}$) as per experimental design. Beds, ridges and mounds were prepared in the respective plots. Farmyard manure (FYM) was incorporated @ $10 \text{ tonnes ha}^{-1}$ and healthy vine cuttings of 10-15 cm size were planted in the spacings fixed as per treatments. Half the dose of N and K and full dose of phosphorus (P) were applied basally and remaining quantity of N and K was given at 45 days after planting (DAP) along with earthing up. Consortium biofertilizer, PGPR Mix 1 developed in the Department of Agricultural Microbiology, College of Agriculture, Vellayani, Kerala was mixed with FYM @ 2 per cent (2 g PGPR Mix 1 in 100 g FYM). From the mixture, 5 g was applied per plant thrice, at the time of planting, 30 DAP and 60 DAP in n_1 . Humic acid @ 5 g l^{-1} , benzyl adenine 50 mg l^{-1} and water were used as g_1 , g_2 and g_3 treatments respectively at a spray

volume of 500 l ha^{-1} and sprayed at 45 and 75 days after planting. All cultural operations were done as per the package of practices recommendation (KAU 2016).

Observations on physiological and biochemical parameters were recorded at 45 days interval. The number of days taken by 50 per cent of the plants to exhibit senescence in each plot was visually observed and recorded as days to senescence. The biomass partitioning in the plants was assessed at the start of senescence and was expressed in percentage. Tuber yield per plot was recorded and per hectare tuber yield was computed. Pooled analysis was also done. The data were analysed statistically and the significance was tested by F-test.

RESULTS AND DISCUSSION

Physiological and biochemical properties

Method of planting and nutrient management + growth promoter combination and their interaction exerted significant influence on physiological attributes of Chinese potato in the study. The variations in growth attributes brought by the differences in plant population at two spacings tried also ensued significant differences in the physiological attributes.

Crop geometry showed a significant effect on LAI (Fig 1a and 1b). Even though the closer spacing of $30 \text{ cm} \times 15 \text{ cm}$ produced lower number of leaves and leaf area per plant compared to wider spacing, the higher plant population (22.22 per m^2) contributed to more number and area of leaves on unit area basis and hence a higher LAI. The observation falls in line with that reported by Sen *et al.* (2014). Chlorophyll content was higher in the bed or ridge planting method with wider spacing (Fig 2a and 2b).

Irrespective of the treatments imposed, CGR was found to increase to a maximum at the maturity stages (90-135 DAP) stipulating the higher biomass accumulation due to tuber bulking (Table 1a and 1b). The DMP, CGR and LAI (Fig 3a, 3b, Tables 1a, 2, 3a) computed revealed higher

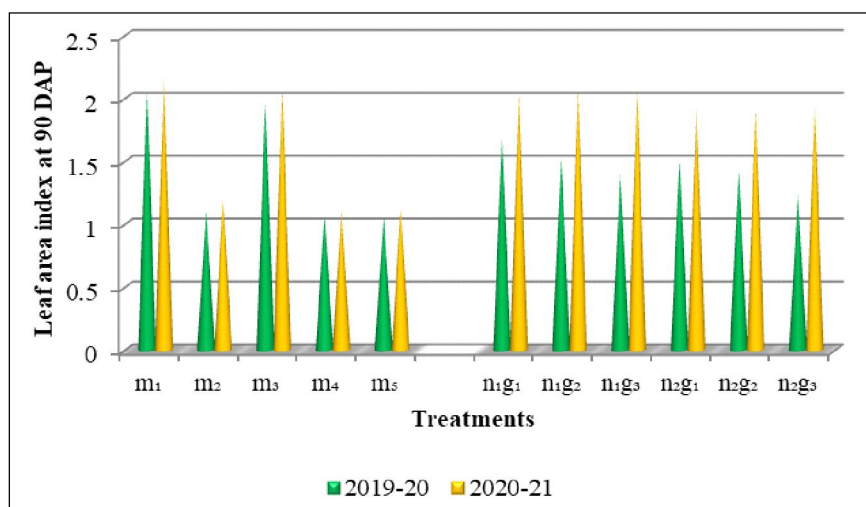


Fig 1a: Effect of method of planting and nutrient management x growth promoter on leaf area index.

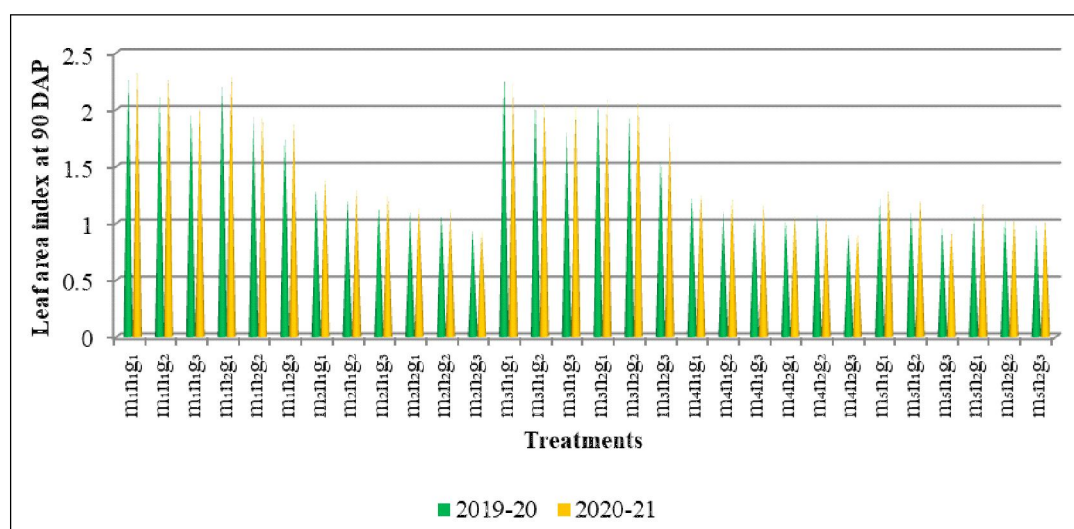


Fig 1b: Interaction effect of method of planting and nutrient management x growth promoter on leaf area index.

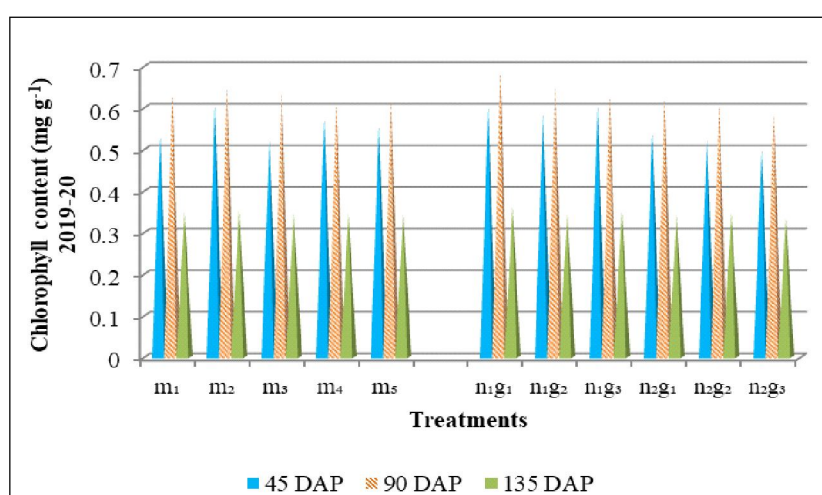


Fig 2a: Effect of method of planting and combination of nutrient management + growth promoter on chlorophyll content, mg g⁻¹ (2019-20).

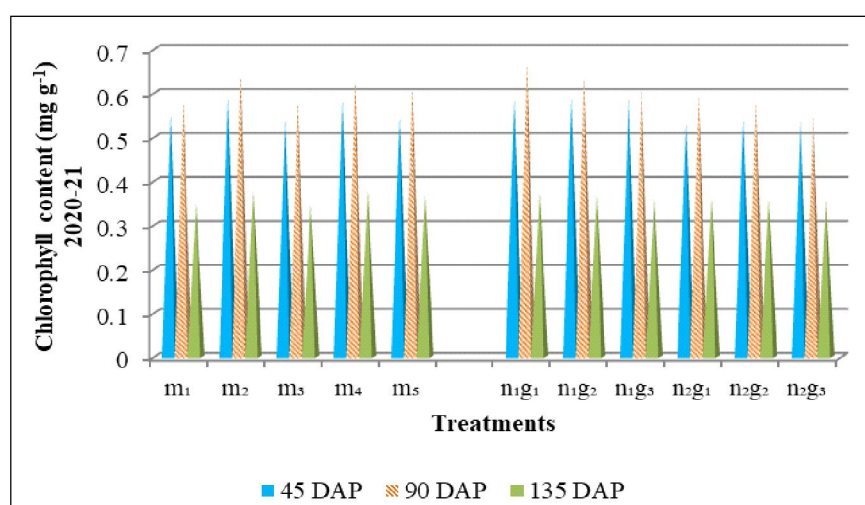


Fig 2b: Effect of method of planting and combination of nutrient management + growth promoter on chlorophyll content, mg g⁻¹ (2020-21).

values in bed planting at closer spacing (m_1) and these correspond to the better growth and yield attributes observed in the treatment. The higher DMP (Fig 3a to 3d) is due to increased number of plants, whereas the highest CGR recorded is attributable to greater photosynthetic efficiency in closely spaced crop (Sen *et al.*, 2014). Higher CGR recorded in the study are in accordance with the results of Malik (2000). Increased biomass production per unit with closer spacing was also documented by Mastiholi *et al.* (2013). Relative growth rate (RGR) and net assimilation

rate (NAR) were higher in bed or ridge with wider spacing of 30 cm x 30 cm (Table 2 and 3a).

The superiority of the combinations containing PGPR Mix 1 (n_1) in physiological parameters *viz.* CGR, RGR, LAI, NAR and chlorophyll content at/ up to 45 DAP might be due to the growth enhancement and reinforced nutrient availability warranted by the plant growth promoting bacteria present in the biofertilizer consortium PGPR Mix 1. At this stage (up to 45 DAP), as growth promoters were not applied the parameters, DMP, CGR

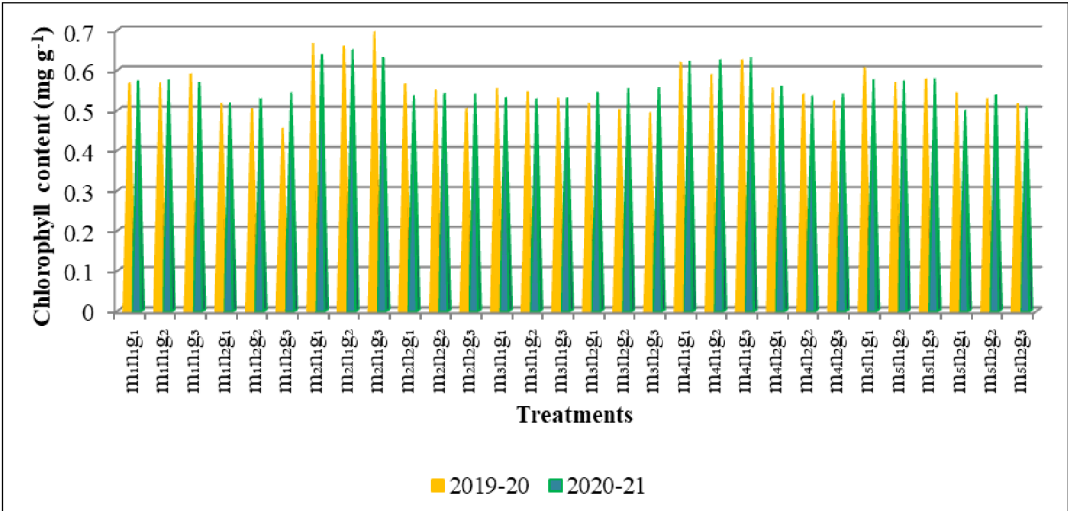


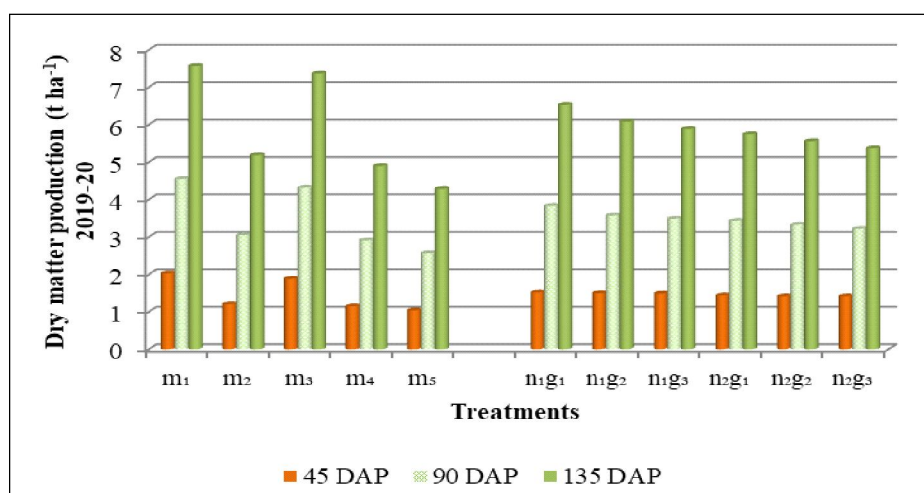
Fig 2c: Interaction effect of method of planting and combination of nutrient management + growth promoter on chlorophyll content, mg g^{-1} .

Table 1a: Effect of method of planting and nutrient management x growth promoter on crop growth rate (CGR), $\text{g m}^{-2} \text{ day}^{-1}$.

Treatments	Crop growth rate					
	2019-20			2020-21		
	Up to 45 DAP	45-90 DAP	90-135 DAP	Up to 45 DAP	45-90 DAP	90-135 DAP
Method of planting						
m_1 - Bed method (30 cm x 15 cm)	4.50	5.61	6.70	4.71	6.65	7.24
m_2 - Bed method (30 cm x 30 cm)	2.70	4.09	4.75	2.82	4.74	5.06
m_3 - Ridge method (30 cm x 15 cm)	4.20	5.40	6.77	4.40	6.30	7.21
m_4 - Ridge method (30 cm x 30 cm)	2.56	3.90	4.42	2.68	4.52	4.70
m_5 - Mound method (30 cm x 30 cm)	2.32	3.39	3.83	2.43	3.93	4.08
SEm ($\pm$)	0.05	0.06	0.06	0.05	0.04	0.06
CD (0.05)	0.142	0.184	0.172	0.142	0.113	0.174
Nutrient management x growth promoter						
n_1g_1 - 60:30:120 kg NPK ha^{-1} + PGPR Mix 1 + Humic acid	3.38	5.13	6.01	3.53	5.95	6.41
n_1g_2 - 60:30:120 kg NPK ha^{-1} + PGPR Mix 1 + Benzyl adenine	3.33	4.64	5.53	3.49	5.50	5.96
n_1g_3 - 60:30:120 kg NPK ha^{-1} + PGPR Mix 1 + Water spray	3.33	4.44	5.32	3.48	5.17	5.73
n_2g_1 - 60:30:120 kg NPK ha^{-1} + Humic acid	3.20	4.42	5.16	3.35	5.14	5.49
n_2g_2 - 60:30:120 kg NPK ha^{-1} + Benzyl adenine	3.15	4.24	4.97	3.30	4.94	5.29
n_2g_3 - 60:30:120 kg NPK ha^{-1} + Water spray	3.17	3.99	4.77	3.31	4.66	5.07
SEm ($\pm$)	0.04	0.06	0.06	0.04	0.06	0.08
CD (0.05)	0.106	0.177	0.182	0.121	0.172	0.218

Table 1b: Interaction effect of method of planting and combination of nutrient management + growth promoter on crop growth rate, g m⁻² day⁻¹.

	2019-20		2020-21	
	Crop Growth Rate			
	45-90 DAP	90-135 DAP	45-90 DAP	90-135 DAP
m ₁ n ₁ g ₁	6.29	7.39	7.32	7.87
m ₁ n ₁ g ₂	5.59	6.82	7.10	7.58
m ₁ n ₁ g ₃	5.46	6.84	6.39	7.61
m ₁ n ₂ g ₁	5.75	6.79	6.71	7.23
m ₁ n ₂ g ₂	5.34	6.34	6.25	6.75
m ₁ n ₂ g ₃	5.24	6.01	6.13	6.38
m ₂ n ₁ g ₁	5.06	5.95	5.82	6.36
m ₂ n ₁ g ₂	4.37	4.92	5.06	5.24
m ₂ n ₁ g ₃	4.25	4.77	4.92	5.08
m ₂ n ₂ g ₁	3.75	4.50	4.37	4.80
m ₂ n ₂ g ₂	3.70	4.31	4.29	4.60
m ₂ n ₂ g ₃	3.39	4.03	3.96	4.29
m ₃ n ₁ g ₁	5.93	7.01	6.91	7.46
m ₃ n ₁ g ₂	5.54	6.92	6.46	7.38
m ₃ n ₁ g ₃	5.21	6.77	6.11	7.22
m ₃ n ₂ g ₁	5.42	6.82	6.33	7.27
m ₃ n ₂ g ₂	5.31	6.58	6.18	7.02
m ₃ n ₂ g ₃	4.98	6.49	5.82	6.92
m ₄ n ₁ g ₁	4.59	5.19	5.29	5.53
m ₄ n ₁ g ₂	4.12	4.68	4.78	4.99
m ₄ n ₁ g ₃	3.89	4.45	4.51	4.73
m ₄ n ₂ g ₁	3.81	4.18	4.41	4.45
m ₄ n ₂ g ₂	3.66	4.09	4.26	4.36
m ₄ n ₂ g ₃	3.33	3.91	3.88	4.16
m ₅ n ₁ g ₁	3.80	4.53	4.41	4.83
m ₅ n ₁ g ₂	3.56	4.32	4.12	4.61
m ₅ n ₁ g ₃	3.39	3.77	3.94	4.01
m ₅ n ₂ g ₁	3.35	3.50	3.89	3.72
m ₅ n ₂ g ₂	3.18	3.49	3.70	3.72
m ₅ n ₂ g ₃	3.03	3.38	3.53	3.59
SEm (±)	0.14	0.14	0.13	0.17
CD (0.05)	0.395	0.408	0.385	0.488

**Fig 3a:** Effect of method of planting and nutrient management x growth promoter on dry matter production, t ha⁻¹ (2019-20).

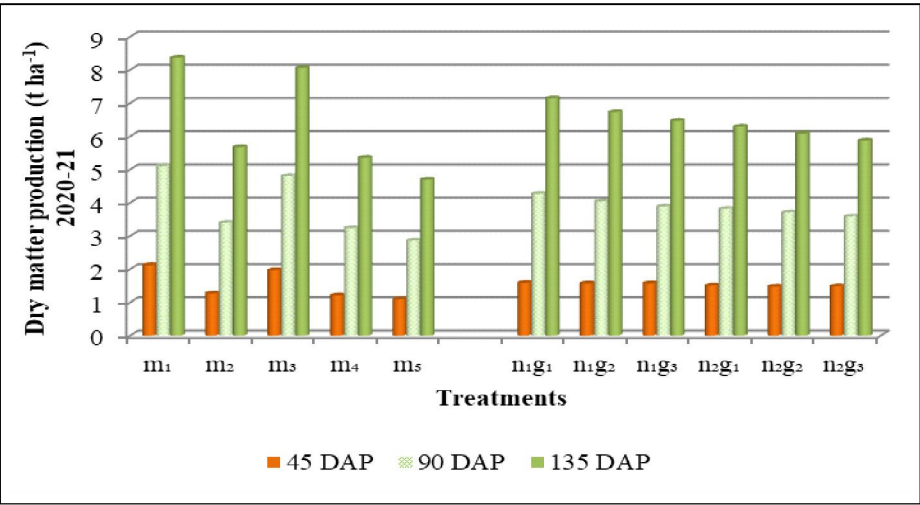


Fig 3b: Effect of method of planting and nutrient management x growth promoter on dry matter production, t ha⁻¹ (2020-21).

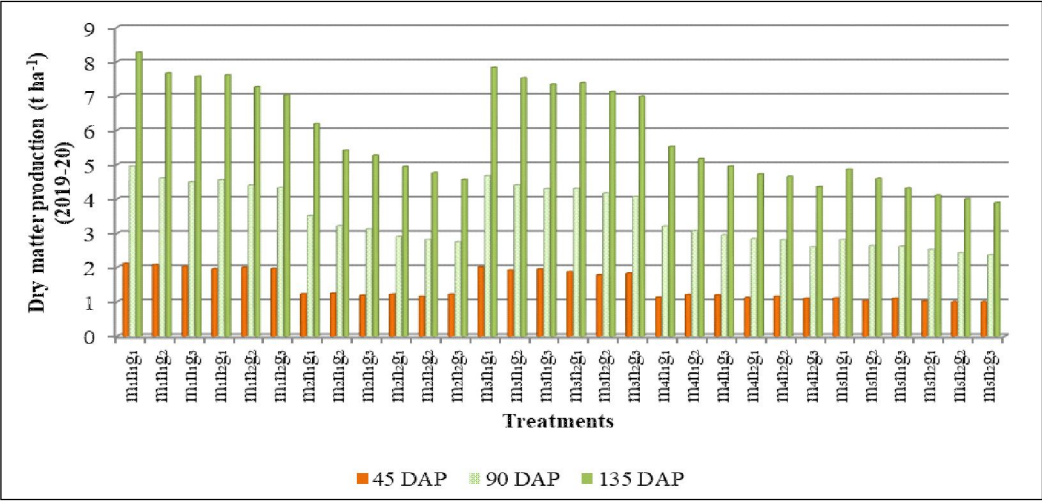


Fig 3c: Interaction effect of method of planting and combination of nutrient management + growth promoter on dry matter production, t ha⁻¹(2019-20).

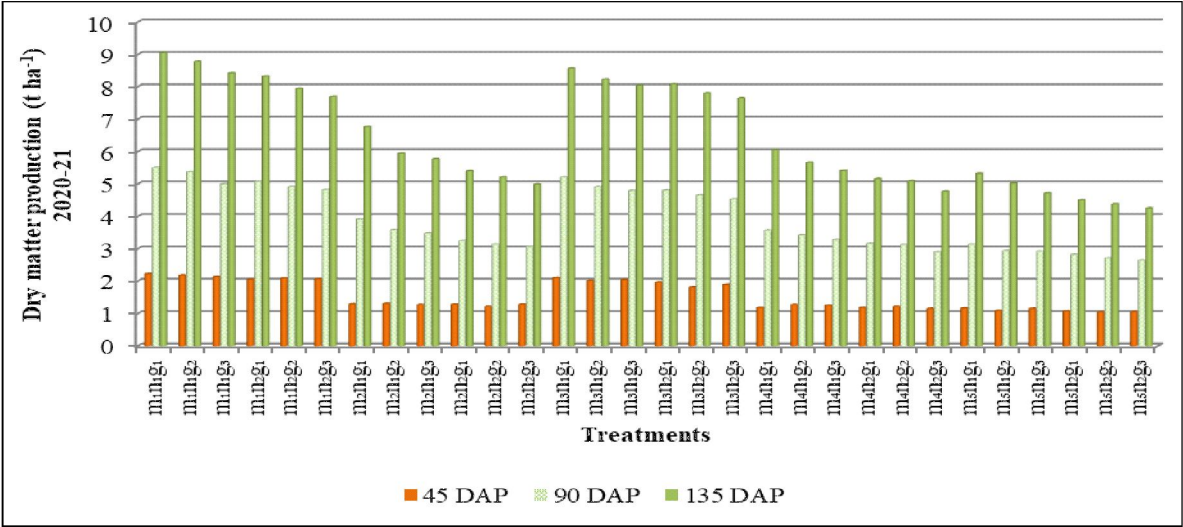


Fig 3d: Interaction effect of method of planting and combination of nutrient management + growth promoter on dry matter production, t ha⁻¹(2020-21).

and LAI of n_2 remained comparable with PGPR applied treatment. At the later stages, the significant effect of the combination, 60:30:120 kg NPK ha⁻¹ + PGPR Mix 1 + humic acid, was clearly visible.

It is might be due to the formation of larger and more number of bundle sheath chloroplast in the humic acid inoculated plants led to increased chlorophyll content (Arumugam *et al.*, 2010). The higher chlorophyll content in

humic acid applied treatments corroborates the results reported by El-Deen *et al.* (2011) in sweet potato. Humic substances and PGPR affected leaf chlorophyll content and photosynthetic ability and Ekin (2019) opined that the mode of action of both might partially be attributed to the N-uptake/assimilation and IAA-like growth-regulating phytohormone activities. Improved growth and physiological processes with the inclusion of PGPR and humic acid in

Table 2: Effect of method of planting and nutrient management × growth promoter on relative growth rate (RGR), g g⁻¹day⁻¹.

Treatments	Relative growth rate (×10 ⁻³)			
	2019-20		2020-21	
	45-90 DAP	90-135 DAP	45-90 DAP	90-135 DAP
Method of planting				
m ₁ - Bed method (30 cm × 15 cm)	17.97	11.29	19.54	10.94
m ₂ - Bed method (30 cm × 30 cm)	20.41	11.75	21.81	11.35
m ₃ - Ridge method (30 cm × 15 cm)	18.34	11.86	19.74	11.46
m ₄ - Ridge method (30 cm × 30 cm)	20.52	11.55	21.92	11.15
m ₅ - Mound method (30 cm × 30 cm)	19.97	11.39	21.36	10.98
SEm (±)	0.19	0.13	0.25	0.11
CD (0.05)	0.589	NS	0.776	NS
Nutrient management × growth promoter				
n ₁ g ₁ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Humic acid	20.95	11.95	22.35	11.55
n ₁ g ₂ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Benzyl adenine	19.71	11.76	21.31	11.35
n ₁ g ₃ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1+ Water spray	19.13	11.55	20.53	11.22
n ₂ g ₁ - 60:30:120 kg NPK ha ⁻¹ + Humic acid	19.45	11.43	20.85	11.03
n ₂ g ₂ - 60:30:120 kg NPK ha ⁻¹ + Benzyl adenine	19.13	11.39	20.53	10.99
n ₂ g ₃ - 60:30:120 kg NPK ha ⁻¹ + Water spray	18.29	11.32	19.69	10.92
SEm (±)	0.30	0.13	0.28	0.15
CD (0.05)	0.839	0.372	0.785	0.428

Table 3a: Effect of method of planting and nutrient management × growth promoter on net assimilation rate (NAR), g cm⁻² day⁻¹.

Treatments	Net assimilation rate (× 10 ⁻⁴)			
	2019-20		2020-21	
	45-90 DAP	90-135 DAP	45-90 DAP	90-135 DAP
Method of planting				
m ₁ - Bed method (30 cm × 15 cm)	2.36	9.42	2.73	9.94
m ₂ - Bed method (30 cm × 30 cm)	3.15	12.13	3.48	12.35
m ₃ - Ridge method (30 cm × 15 cm)	2.33	9.97	2.68	10.25
m ₄ - Ridge method (30 cm × 30 cm)	3.11	11.85	3.47	12.09
m ₅ - Mound method (30 cm × 30 cm)	2.82	10.39	3.06	10.61
SEm (±)	0.03	0.13	0.03	0.14
CD (0.05)	0.089	0.415	0.086	0.439
Nutrient management × growth promoter				
n ₁ g ₁ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Humic acid	2.91	11.20	3.28	11.65
n ₁ g ₂ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Benzyl adenine	2.74	10.79	3.08	10.90
n ₁ g ₃ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Water spray	2.73	11.09	3.06	11.35
n ₂ g ₁ - 60:30:120 kg NPK ha ⁻¹ + Humic acid	2.77	10.37	3.06	10.68
n ₂ g ₂ - 60:30:120 kg NPK ha ⁻¹ + Benzyl adenine	2.69	10.18	3.04	10.57
n ₂ g ₃ - 60:30:120 kg NPK ha ⁻¹ + Water spray	2.69	10.88	3.00	11.13
SEm (±)	0.03	0.14	0.04	0.15
CD (0.05)	0.090	0.386	0.120	0.428

the management practice of Chinese potato thus resulted in increased values of the growth indices viz., CGR, RGR and NAR.

The delay in senescence in the treatment combinations (more than 116 days to senescence) involving BA (g₂) may be attributed to its effect on promotion of leaf growth, inhibition of leaf senescence and preservation of chlorophyll (Fig 4). Cytokinin application in plants results in enhanced cell division and shoot initiation (Jha and Saraf, 2015) by influencing their physiological and developmental mechanisms. Benzyl adenine is a modified cytokinin and regarded as an anti senescent (Parmar *et al.*, 2021). Other physiological processes such as nutritional signaling and expansion of leaf are also greatly influenced by cytokinins (Wong *et al.*, 2015) which have a bearing on the retention of leaf greenness and initiation of senescence.

The biomass accumulation varied significantly with the main and subplot treatments during both the years (Table 4). As expected in tuber crops, the maximum accumulation was seen in tubers (56.61-76.42%) followed by stem (15.85-38.19%) and leaves (5.79-8.28%), accounting for the partitioning in the crop. The partitioning of photoassimilates from the source to the sink depends on many factors, photosynthetic capacity, environmental stress, nutrient availability, etc. (Paul *et al.*, 2017). Growth promoters when applied can curtail excessive vegetative growth, to improve photosynthetic efficiency and improve source-sink relationship (Deol *et al.*, 2018).

Tuber yield is determined by the fraction of total biomass that is partitioned to the tuber. Translocation of assimilates was lower for leaves and stems and highest for tubers in potato (Geremew *et al.*, 2007).

The growth hormones released or synthesized by the microbes in PGPR might have accelerated mobility of photosynthates from the source to the sink (Desai and Thirumala, 2014). Humic acid in this study showed a greater effect on the growth of roots than on shoots indicating a probably greater recourse allocation toward the roots. This is in agreement with the results of Turkmen *et al.* (2004). Efficient use of resources, increased nutrient availability of essential nutrients resulted in the greater partitioning of assimilates to tubers as a result of effects of inputs used in treatments on physical, chemical and biological properties of soil, which was higher in the second year, particularly under the influence of higher rainfall. The split application of chemical fertilizers and PGPR Mix 1 would have resulted in slower, extended availability of all essential nutrients leading to an efficient partitioning to tubers.

Tuber yield

Per hectare tuber yield was significantly highest in bed method of planting with closer spacing of 30 cm × 15 cm [20.18 and 19.76 t ha⁻¹]. Increase in plant density directly influenced the per hectare tuber yield (Table 5a and 5b). The higher plant density under narrow spacing (30 cm × 15 cm)

resulted in better canopy coverage and LAI indicating a reinforced source capacity and photosynthetic ability contributing to the tuber sinks and higher yields. It is surmised that the accrue ment is mainly due to the increase in plant population despite a compromise in per plant yields. Increased tuber yield with closer spacing were also documented in potato (Aminifard *et al.* 2012).

Inclusion of PGPR along with humic acid in the nutrient management strategy could result in 19.7 to 21.7 per cent increase in the per hectare yields compared to that without PGPR and humic acid. The improved nutrient status of plants due to chemical fertilizers, application PGPR Mix 1 and hormonal effect of humic acid would also have contributed to the higher yield (Table 5a). The results are

Table 3b: Interaction effect of method of planting and combination of nutrient management + growth promoter on net assimilation rate, g cm⁻² day⁻¹.

Treatments	Net Assimilation Rate	
	90-135 DAP	
	2019-20	2020-21
m ₁ n ₁ g ₁	9.52	10.08
m ₁ n ₁ g ₂	9.35	9.78
m ₁ n ₁ g ₃	9.83	10.85
m ₁ n ₂ g ₁	9.12	9.49
m ₁ n ₂ g ₂	9.26	9.77
m ₁ n ₂ g ₃	9.46	9.69
m ₂ n ₁ g ₁	13.96	14.08
m ₂ n ₁ g ₂	11.63	11.59
m ₂ n ₁ g ₃	12.20	12.09
m ₂ n ₂ g ₁	11.75	12.21
m ₂ n ₂ g ₂	11.21	11.34
m ₂ n ₂ g ₃	12.04	12.79
m ₃ n ₁ g ₁	9.01	9.90
m ₃ n ₁ g ₂	9.76	10.38
m ₃ n ₁ g ₃	10.41	10.27
m ₃ n ₂ g ₁	9.69	10.34
m ₃ n ₂ g ₂	9.68	9.91
m ₃ n ₂ g ₃	11.26	10.70
m ₄ n ₁ g ₁	12.57	13.03
m ₄ n ₁ g ₂	11.92	11.79
m ₄ n ₁ g ₃	12.01	11.75
m ₄ n ₂ g ₁	11.74	11.97
m ₄ n ₂ g ₂	11.01	11.60
m ₄ n ₂ g ₃	11.85	12.39
m ₅ n ₁ g ₁	10.97	11.18
m ₅ n ₁ g ₂	11.29	10.96
m ₅ n ₁ g ₃	11.01	11.80
m ₅ n ₂ g ₁	9.55	9.40
m ₅ n ₂ g ₂	9.75	10.25
m ₅ n ₂ g ₃	9.77	10.08
SEm (±)	0.31	0.34
CD (0.05)	0.864	0.957

Table 4: Effect of method of planting and nutrient management x growth promoter on biomass partitioning (BP), per cent.

Treatments	Biomass partitioning					
	2019-20			2020-21		
	Stem	Leaf	Tuber	Stem	Leaf	Tuber
Method of planting						
m ₁ - Bed method (30 cm × 15 cm)	35.18 (33.34)	14.43 (6.21)	51.05 (60.47)	35.28 (33.61)	14.56 (6.32)	50.91 (60.18)
m ₂ - Bed method (30 cm × 30 cm)	24.85 (17.72)	6.31 1(7.89)	59.60 (74.39)	24.74 (17.66)	16.36 (7.94)	60.06 (74.76)
m ₃ - Ridge method (30 cm × 15 cm)	37.00 (36.33)	14.17 (6.00)	49.39 (57.60)	37.16 (36.57)	14.22 (6.04)	49.30 (57.45)
m ₄ - Ridge method (30 cm × 30 cm)	25.61 (18.75)	16.39 (7.97)	59.76 (74.61)	24.51 (17.36)	16.39 (7.97)	60.10 (74.96)
m ₅ - Mound method (30 cm × 30 cm)	27.47 (21.37)	15.83 (7.45)	57.55 (71.18)	27.42 (21.33)	15.88 (7.49)	57.69 (71.35)
SEm (±)	1.43	0.08	0.31	1.60	0.12	0.68
CD (0.05)	4.423	0.250	0.94	4.940	0.372	2.100
Nutrient management x growth promoter						
n ₁ g ₁ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Humic acid	29.12 (24.12)	15.64 (7.29)	56.20 (68.88)	28.95 (23.92)	15.63 (7.28)	56.35 (68.96)
n ₁ g ₂ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Benzyl adenine	30.26 (25.89)	15.36 (7.04)	55.24 (67.27)	30.09 (25.67)	15.46 (7.13)	55.38 (67.36)
n ₁ g ₃ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1+ Water spray	30.84 (26.71)	15.34 (7.02)	54.79 (66.53)	30.54 (26.34)	15.40 (7.08)	55.03 (66.81)
n ₂ g ₁ - 60:30:120 kg NPK ha ⁻¹ + Humic acid	30.16 (25.71)	15.44 (7.11)	55.54 (67.75)	29.78 (25.30)	15.46 (7.13)	55.70 (67.84)
n ₂ g ₂ - 60:30:120 kg NPK ha ⁻¹ + Benzyl adenine	30.20 (25.78)	15.36 (7.05)	55.32 (67.40)	30.09 (25.80)	15.43 (7.11)	55.20 (67.13)
n ₂ g ₃ - 60:30:120 kg NPK ha ⁻¹ + Water spray	29.56 (24.80)	15.43 (7.11)	55.72 (68.07)	29.50 (24.81)	15.50 (7.18)	56.01 (68.35)
SEm (±)	0.40	0.08	0.32	0.58	0.14	0.85
CD (0.05)	NS	NS	0.91	NS	NS	NS

Figures in parenthesis are mean of original values; Data subjected to arcsine transformation.

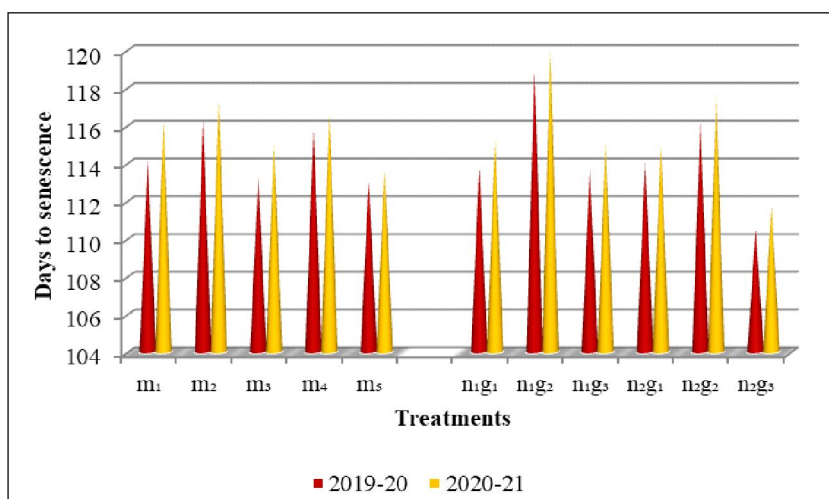


Fig 4: Effect of method of planting and nutrient management x growth promoter on days to senescence.

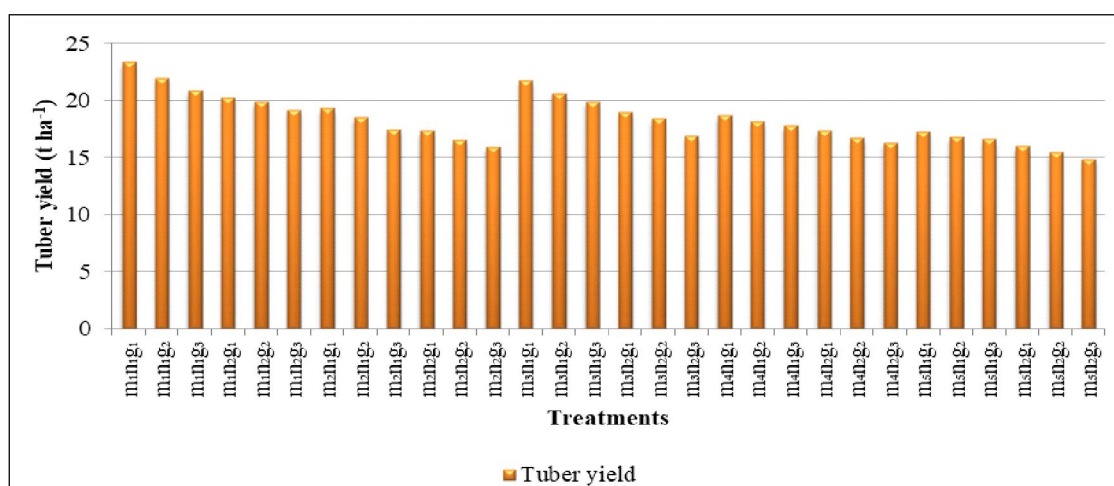


Fig 5: Interaction effect of method of planting x nutrient management + growth promoters on per hectare tuber yield (pooled mean), t ha⁻¹.

Table 5a: Effect of method of planting and nutrient management x growth promoter on tuber yield, t ha⁻¹.

Treatments	Tuber yield (t ha ⁻¹)	
	2019-20	2020-21
Method of planting		
m ₁ - Bed method (30 cm × 15 cm)	20.18	19.76
m ₂ - Bed method (30 cm × 30 cm)	17.28	16.19
m ₃ - Ridge method (30 cm × 15 cm)	18.60	18.67
m ₄ - Ridge method (30 cm × 30 cm)	17.82	15.50
m ₅ - Mound method (30 cm × 30 cm)	16.58	14.58
SEm (±)	0.10	0.10
CD (0.05)	0.302	0.294
Nutrient management x growth promoter		
n ₁ g ₁ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Humic acid	19.92	20.28
n ₁ g ₂ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Benzyl adenine	19.05	19.40
n ₁ g ₃ - 60:30:120 kg NPK ha ⁻¹ + PGPR Mix 1 + Water spray	18.29	18.84
n ₂ g ₁ - 60:30:120 kg NPK ha ⁻¹ + Humic acid	17.70	18.29
n ₂ g ₂ - 60:30:120 kg NPK ha ⁻¹ + Benzyl adenine	17.23	17.60
n ₂ g ₃ - 60:30:120 kg NPK ha ⁻¹ + Water spray	16.37	16.94
SEm (±)	0.12	0.10
CD (0.05)	0.332	0.283

Table 5b: Interaction effect of method of planting and combination of nutrient management + growth promoter on tuber yield, t ha⁻¹.

Treatments	Tuber yield (t ha ⁻¹)	
	2019-20	2020-21
m ₁ n ₁ g ₁	22.84	23.92
m ₁ n ₁ g ₂	21.19	22.78
m ₁ n ₁ g ₃	20.08	21.69
m ₁ n ₂ g ₁	19.27	21.28
m ₁ n ₂ g ₂	19.02	20.71
m ₁ n ₂ g ₃	18.67	19.76
m ₂ n ₁ g ₁	18.82	19.88
m ₂ n ₁ g ₂	18.42	18.62
m ₂ n ₁ g ₃	17.05	17.95
m ₂ n ₂ g ₁	17.35	17.35
m ₂ n ₂ g ₂	16.32	16.82
m ₂ n ₂ g ₃	15.72	16.19
m ₃ n ₁ g ₁	21.48	22.06
m ₃ n ₁ g ₂	20.11	21.17
m ₃ n ₁ g ₃	19.40	20.49
m ₃ n ₂ g ₁	17.84	20.14
m ₃ n ₂ g ₂	17.61	19.27
m ₃ n ₂ g ₃	15.15	18.67
m ₄ n ₁ g ₁	18.57	18.82
m ₄ n ₁ g ₂	18.20	18.11
m ₄ n ₁ g ₃	17.96	17.67
m ₄ n ₂ g ₁	17.71	16.99
m ₄ n ₂ g ₂	17.30	16.18
m ₄ n ₂ g ₃	17.14	15.50
m ₅ n ₁ g ₁	17.88	16.74
m ₅ n ₁ g ₂	17.34	16.32
m ₅ n ₁ g ₃	16.93	16.37
m ₅ n ₂ g ₁	16.34	15.69
m ₅ n ₂ g ₂	15.86	15.03
m ₅ n ₂ g ₃	15.15	14.58
SEm (±)	0.26	0.23
CD (0.05)	0.743	0.634

agreement with those reported by Ezzat *et al.* (2009) and (Yasmin *et al.*, 2020).

Bed method of planting at 30 cm x 15 cm spacing along with application of 60:30:120 kg NPK ha⁻¹ + PGPR Mix 1 + humic acid (m₁n₁g₁) resulted in maximum yield in both the years of experimentation (22.84 and 23.92 t ha⁻¹). Pooled analysis also revealed the same trend (Fig 5b).

CONCLUSION

The study revealed the superiority of bed method of planting at 30 cm x 15 cm spacing with the application of 60:30:120 kg NPK ha⁻¹ + PGPR Mix 1 + humic acid as the most productive resource management practice in Chinese potato.

Conflict of interest

There is no conflict of interest among the authors in publishing the article.

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