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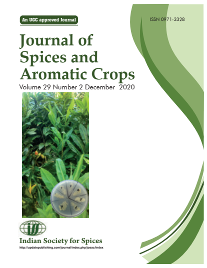

Growth, nutrient uptake and yield of ginger as impacted by potting media, foliar nutrition and microbial inoculants

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Abstract

Experiments were conducted during 2017-19 at the Integrated Farming System Research Station, Karamana, Kerala Agricultural University for assessing the impact of quantity of potting media, foliar application of multinutrient mixture IISR Power Mix G and microbial inoculants Arbuscular Mycorrhizal Fungi (AMF) and *Trichoderma* on the growth, nutrient uptake and yield of ginger variety *Karthika* grown as pot culture. The study revealed that 12 and 15 kg of potting media filled grow bags could produce comparable yields of ginger significantly higher than that obtained with 9 kg of potting media. Application of IISR Power Mix G @ 0.5% at 2 and 3 months of planting enhanced the yield of ginger to the tune of 11 per cent in comparison to control. Microbial inoculants AMF (5 g plant^{-1}) and *Trichoderma* (1 kg mixed with 90 kg FYM and 10 kg neem cake and 250 g of the mixture used) applied at planting time followed by *Trichoderma* at 1 month after planting resulted in higher fresh ginger yield of 596.67 g bag^{-1} and was comparable to 550 g of fresh ginger obtained with application of AMF and *Trichoderma* at planting.

Keywords: AMF, multi-nutrient mixture, polybag culture, *Trichoderma*

Introduction

Ginger (*Zingiber officinale*) occupies a prime position among spice crops in India. India is a major producer and grows ginger in an area of 1.17 lakh ha accounting to an annual production of 5.29 lakh tons with an average productivity of 4.3 t ha^{-1} (Spices Board 2018). In Kerala, ginger is an integral crop component of homesteads grown for its medicinal value and year round demand for both fresh vegetable and dried spice. There are reports of successful cultivation of ginger in homesteads using growbags (Abraham 2016) and gunny bags (IISR 2016; Krishi Jagaran 2019). However, not much work was conducted to standardize an optimum quantity of container media for growing ginger and hence the present experiment aimed to address this issue.

Soil limitations can lead to nutrient deficiencies and foliar nutrition is well established as a corrective factor in overcoming such limitations. There are reports on improved growth and yield of ginger with $ZnSO_4$ (0.5%) spray (Singh

& Dwivedi 2007). Foliar fertilizers with slow release rate are thus effective in counteracting the reduced mobility and bioavailability of Zn (Doolette *et al.* 2018). Supplemental foliar nourishment is a booster to attain better yield by correcting soil limitations.

Bioinoculants like AMF and *Trichoderma* through their growth promoting effects are reported to enhance crop yields. They are reported to improve root development leading to better nutrient uptake by crops and hence higher yields. Additionally, tolerance to abiotic stress and resistance against plant pathogens are also reported with the use of these bio inoculants (Bharat 2017). AMF inoculation also helps selective activation of beneficial soil microbes (Tahat & Sijam 2012). AMF belonging to Gigasporaceae have revealed prominent nutrient uptake capacity compared to plant protection effects, whereas the members of Glomeraceae ensured more of protection from pathogen invasions (Maherali & Klironomos 2007). Hence the present study also aimed at developing a production package for better yield of ginger through the inclusion of bio inoculants and foliar spray of IISR Power mix G in the crop management schedule.

Materials and methods

The experiment was conducted at the Integrated Farming System Research Station (IFSRS), Kerala Agricultural University, Karamana, Thiruvananthapuram, Kerala (8^0 48′ 18′′ N Latitude and 76^0 96′ 57′′E Longitude). The ginger variety used was Karthika developed by Kerala Agricultural University (selection from cv. *Maran* through tissue culture and somaclonal variation techniques). The study was conducted as two experiments as mentioned below.

Weight of growing media and multinutrient foliar sprays on the growth and yield of ginger grown in grow bags

The two factors studied under this experiment were quantity of potting media (P) and crop nutrition (N). The design of the experiment was Factorial CRD with three replications. The potting media was prepared by mixing red soil, rock sand, coir pith and FYM in the ratio 1: 0.5: 0.5:1 on volume basis and was enriched with neem cake (4.8% N) @50 kg per 500 kg mixture. The initial nutrient status of the mixture was 303 kg available N, 26 kg P_2O_5 and 280 kg K_2O ha^{-1} and 80, 0.41 and 1.26 mg kg^{-1} of Mg, B and Zn. Nutrients, pH and organic carbon were estimated as per standard procedures (Jackson 1973) including Microkjeldhal method (N), nitric - perchloric acid digestion and spectrophotometry using Vanadomolybdophosphoric yellow colour method (P) and Nitric - perchloric acid digestion and Atomic Absorption Spectrophotometry (Zn). B was estimated based on azomethine method and Mg through EDTA titration method. Potting media had a pH of 6.10 and the organic carbon content was 1.34%. Measurement of pH was done using pH meter with glass electrode and organic carbon was determined using the Walkely and Black rapid titration method.

Under factor P, grow bags of three sizes were included (P_1 - 30 cm long, 36 cm wide (0.108 m^3) holding 9 kg of potting media, P_2 - 36 cm long, 45 cm wide (0.162 m^3) holding 12 kg of potting media, P_3 - 42 cm long, 53 cm wide (0.223 m^3) holding 15 kg of potting media). Under factor N, four different nutrient packages were tested (N_1 - Package of Practices Recommendation (POP) for crops as per KAU wherein FYM was applied @ 30 t ha^{-1} as basal dose followed by N: P: K @75: 50:50 kg ha^{-1} (Full P and half the dose of K as basal, 50% N at 60 DAP, remaining 50% N and 50% K at 120 DAP), N_2 - N_1 + Nutrient formulation from IISR - "Power mix G" (containing 0.5% K, 0.1% Mg, 0.2% B and 0.3% Zn) sprayed @ 0.5% at 60 and 90 DAS, N_3 - Organic nutrition (FYM @30 t ha^{-1}as basal dose followed by top dressing of FYM to supply the recommended N on equivalent basis at 60 and 120 DAP) and N_4 - N_3+ IISR - "Power mix G"@ 0.5% at 60 and 90 DAS.

Five plants were maintained per replication. The rhizomes were sown in protrays, which were transplanted in grow bags at one month after sowing. Periodic observations on growth attributes were recorded and the crop was harvested at 9 months of planting. Observations on fresh and dry ginger yield and root growth in terms of root length and root biomass were recorded at harvest. Dry ginger recovery was estimated by drying known weight of fresh ginger in hot air oven at a temperature of 60^{o}C for 48 hours, wherein the moisture content of rhizomes was reduced to a level of 10%.

Microbial inoculants in improving growth and yield of ginger

Based on the conclusions of Experiment I, a promising package for grow bag grown ginger was arrived (Potting media @12 kg/bag, organic crop nutrition, supplemental foliar spray of multinutrient mixture IISR Power mix G (0.5%) at 60 and 90 DAS). This was decided as control (T_7) treatment and was uniformly followed for all treatments. Further improvement in crop productivity using microbial inoculants was studied in Experiment II. Bio inoculants were imposed on all treatments except control as follows - T_1 (AMF at planting), T_2 (*Trichoderma* at planting), T_3 (*Trichoderma* at planting and 30 DAP), T_4 (AMF+ *Trichoderma* at planting), T_5 (AMF + *Trichoderma* at planting followed by *Trichoderma* at 30 DAP) and T_6 (*Trichoderma* @30 days interval throughout the crop growth).

The species of bioinoculants were *Trichoderma* sp. (KAU formulation) and AMF (KAU) including *Glomus fasciculatum, G. acaulospora, G. mossaea, G. etunicatum* and *Gigaspora* sp. AMF was applied @ 5 g plant^{-1} during planting of rhizomes in growbags. *Trichoderma* (1 kg) was multiplied in cowdung - neem cake mixture prepared in the ratio 90:10 kg. The mixture was incubated for 2 weeks and was applied @ 250 g per grow bag.

The design of the experiment was CRD with three replications. The initial nutrient status of the potting mixture was 298 kg of available N, 25 kg P, 285 kg K ha^{-1} and 78, 0.42 and 1.22 mg kg^{-1} of Mg, B and Zn. The pH of the mixture was 6.2 and organic carbon content was 1.28 per cent. Five observational plants were maintained per replication. Rhizomes were sown in protrays and the sprouted rhizomes were transplanted in grow bags after one month of sowing. Periodic observations on growth attributes were recorded. The crop was harvested at 9 months after planting and the observations on yield, root biomass and root length were recorded. Plant samples were analysed for major nutrients and uptake recorded. The data generated were subjected to statistical analysis and the significance tested as per analysis of variance (Panse & Sukhatme 1967).

Results and discussion

Weight of growing media and multinutrient foliar spray

Growth characters

Growth characters including plant height, number of tillers and number of leaves were observed at two stages *i.e.,* 3 and 6 months after sowing (Table 1). At 3 MAS, none of the treatments could significantly influence the growth parameters studied. However, at 6 MAS, all the growth parameters were comparable for ginger plants grown in bags holding 12 and 15 kg media which was significantly superior to those grown in bags holding 9 kg of the media. With increase in the quantity of growing media, nutrient addition was more in bags of bigger size compared to lesser size bags resulting in enhancement in growth parameters.

Regarding crop nutrition, none of the treatments produced a significant impact on the growth characters at 3 months. However at 6 MAS, the treatments which received foliar nutrition of IISR Power mix G *ie.,* N_2 (Package of Practices Recommendation for crops as per KAU + IISR Power mix G as foliar spray) and N_4 (Organic nutrition + IISR Power mix G as foliar spray) recorded higher and comparable growth attributes significantly superior to no application of IISR Power mix as in N_1 and N_3. This suggests that ginger being an exhaustive crop, recommended crop nutrition if supplemented with such foliar feeds could result in improved growth. The foliar nutrient formulation had Mg, Zn and B nutrients

Table 1. Growth of ginger as influenced by weight of potting media and foliar nutrition

Treatment	Plant height (cm)		Number of tillers plant^{-1}		Number of leaves plant^{-1}	
	3 months	6 months	3 months	6 months	3 months	6 months
Weight of potting media (P)						
P_1	37.68	55.46	3.90	11.83	35.72	154.67
P_2	42.08	71.33	5.20	14.89	42.88	222.22
P_3	45.33	74.25	5.63	15.68	45.32	235.30
CD (0.05)	2.97	3.15	0.60	0.87	3.54	14.65
Foliar nutrition (N)						
N_1	41.09	64.61	4.59	13.63	40.95	196.11
N_2	42.04	69.39	4.91	14.66	41.99	212.22
N_3	42.03	64.94	4.99	13.52	40.31	193.26
N_4	41.61	69.11	5.16	14.72	41.98	214.66
CD (0.05)	NS	3.64	NS	1.00	NS	16.92

added in it, which are known for growth promotion. Mehta *et al*. (2017) observed a similar improvement in growth attributes of garlic when the crop was provided with supplemental foliar nutrient sprays. When plants are exposed to high Zn concentration, absorbed Zn via roots get complexed with P compounds to form Zn phytate, as a defense mechanism to prevent further translocation to shoots (Kopittke *et al.* 2011). This detoxification mechanism decreases the mobility and bioavailability of Zn in leaves. Foliar fertilizers with slow release rate are effective in counteracting such type of reduced mobility and bioavailability of nutrients (Doolette *et al.* 2018).

Root growth, dry matter production and nutrient uptake

The root length (38.98 cm) and root weight (159.1 g) were found higher for plants grown in grow bags holding 15 kg of potting media and were comparable to plants grown in 12 kg bags (37.21 cm and 153.39 cm respectively) (Table 2). This can be related to the enhanced nutrient supply ensured with increase in quantity of potting media. Also, the container width was more for grow bags holding 15 and 12 kg media allowing horizontal proliferation of roots. Supplemental foliar sprays of IISR Power mix in treatments N_2 and N_4 improved the root growth significantly compared to non application. Root growth was found significantly reduced in 9 kg bag possibly due to space constraint for root proliferation and lower nutrient availability.

Grow bags holding higher quantities (15 and 12 kg) of the potting media recorded higher dry matter production of 142.77 and 137.36 g plant^{-1} respectively, significantly higher than that recorded with 9 kg media (117.48 g plant^{-1}). Foliar sprays of IISR Power mix could significantly improve the dry matter production (DMP) compared to no foliar sprays due to enhancement in shoot and root growth (Tables 1 & 2).

The uptake of major nutrients nitrogen, phosphorus and potassium by the crop was significantly higher in grow bags holding 15 kg of the potting media compared to 12 and 9 kg bags. The treatments which received supplemental nutrient sprays could register significantly higher uptake of all these major nutrients compared to no application. Supplemental foliar spray of IISR Power mix (N_2 and N_4) also enhanced the DMP significantly over no application.

Yield

Plants raised in bags having higher quantity of media (15 and 12 kg) recorded fresh ginger yields of 468.75 and 447.5 g plant^{-1} respectively and were significantly superior to those grown in bags containing 9 kg (372.08 g plant^{-1}) (Table

Table 2. Dry matter production and root growth of ginger as influenced by weight of potting media and foliar nutrition

Treatment	Dry matter production (g plant^{-1})	Root length (cm)	Root biomass (g)
Weight of potting media (P)			
P_1	117.48	29.24	116.83
P_2	137.36	37.21	153.39
P_3	142.77	38.98	159.10
CD (0.05)	5.53	2.15	3.36
Foliar nutrition (N)			
N_1	125.84	33.29	137.78
N_2	137.80	36.33	148.77
N_3	130.05	34.08	137.84
N_4	136.45	36.87	148.04
CD (0.05)	6.39	2.48	3.88

Table 3. Nutrient uptake and yield of ginger as influenced by weight of potting media and foliar nutrition

Treatment	Nutrient uptake (g per 200 plants)			Fresh ginger yield (g plant^{-1})	Dry ginger yield (g plant^{-1})
	Nitrogen	Phosphorus	Potassium		
Weight of potting media (P)					
P_1	189.16	61.43	253.08	372.08	72.11
P_2	231.56	83.14	315.98	447.50	93.87
P_3	241.33	90.20	341.43	468.75	96.69
CD (0.05)	8.05	2.67	8.93	29.33	3.25
Foliar nutrition (N)					
N_1	210.35	72.29	291.09	408.89	83.81
N_2	229.16	82.16	314.31	451.67	91.41
N_3	216.39	75.80	295.10	406.67	82.90
N_4	226.84	82.76	313.49	450.56	92.11
CD (0.05)	9.29	3.09	10.32	33.87	3.76

3). Regarding dry ginger yields also, the same trend followed and bags which had 15 and 12 kg media recorded significantly higher dry ginger yields compared to 9 kg bags. Significantly higher yields were recorded with supplemental foliar sprays of IISR Power Mix G, attributed to well balanced nutrition.

Effect of microbial inoculants

Growth characters

The growth characters studied were plant height, number of tillers and number of leaves plant^{-1} (Table 4). At 3 MAS, none of the treatments could

Table 4. Growth of ginger as influenced by microbial inoculants

Treatment	Plant height (cm)		Number of tillers plant^{-1}		Number of leaves plant^{-1}	
	3 months	6 months	3 months	6 months	3 months	6 months
T_1	51.47	73.33	5.80	16.53	50.71	251.26
T_2	47.83	71.07	5.83	14.73	50.08	245.78
T_3	49.00	74.07	6.07	17.17	51.50	250.89
T_4	53.60	78.20	6.73	19.17	54.61	275.11
T_5	54.80	79.80	6.97	19.83	55.55	281.11
T_6	51.80	75.93	6.07	18.33	50.60	262.61
T_7	44.31	70.87	5.20	14.07	40.40	225.44
CD (0.05)	NS	4.51	NS	1.83	5.52	31.54

significantly influence the plant height as well as tiller number plant^{-1}. However, leaf number was significantly influenced by treatment T_5 (AMF and *Trichoderma* at planting followed by *Trichoderma* at 30 DAP) registering higher leaf number of 55.55 comparable to that of 54.61 by treatment T_4 (AMF and *Trichoderma* at planting). The leaf number was the least with T_7 (40.4). At 6 months stage, all the treatments significantly influenced crop growth with treatments T_4 and T_5 registering comparable and superior performance for all the attributes studied compared to other treatments.

Root growth, dry matter production and nutrient uptake

Root growth (Table 5) in terms of length of roots were comparable for 3 treatments *viz*., T_5 (53.36), T_4 (51.44) and T_6 (49.0) and significantly higher than other treatments. Similar trend was noticed for root biomass also. Treatments T_5 and T_4 registered comparable and higher DMP of 188.6 and 179.03 g plant^{-1} respectively, followed by T_6 (171.82 g). Improved growth in terms of plant height, tiller number and leaf number as noticed in these treatments (Table 4) could be related with higher DMP. Uptake of nitrogen and potassium worked out for 200 plants was higher and comparable for treatments T_5 (309.31 and 350.8 kg ha^{-1} respectively) and T_4 (296.70 and 336.08 kg ha^{-1}). Phosphorus uptake was significantly highest for treatment T_5. Improvement in nutrient uptake could be linked to higher dry matter production (Table 5).

Yield

Treatments T_5 and T_4 registered significantly higher and comparable yields of 596.67 and 550.0 g plant^{-1} respectively (Table 6). This was followed by treatment T_6 (*Trichoderma* applied at 30 days interval throughout entire crop growth) which registered an yield of 523.33g plant^{-1}. Several workers have reported the significant effect of AMF in improving the yield of ginger (Santos 2010; Yunus *et al*. 2014; Abbasi *et al*. 2015; Li *et al*. 2015; Hijri 2016). Beneficial effects of *Trichoderma* in improving crop growth has been

Table 5. Dry matter production and root growth of ginger as influenced by microbial inoculants

Treatment	DMP (g plant^{-1})	Root length (cm)	Root biomass (g)
T_1	158.49	44.89	133.33
T_2	149.86	42.67	126.33
T_3	163.39	44.22	128.78
T_4	179.03	51.44	187.78
T_5	188.60	53.36	205.56
T_6	171.82	49.00	152.78
T_7	140.81	39.22	122.22
CD (0.05)	10.71	5.33	50.42

Table 6. Nutrient uptake and yield of ginger as influenced by microbial inoculants

Treatment	Nutrient uptake (g per 200 plants)			Fresh ginger yield (g $plant^{-1}$)	Dry ginger yield (g $plant^{-1}$)
	Nitrogen	Phosphorus	Potassium		
T_1	247.25	68.15	283.70	511.67	103.17
T_2	233.78	62.94	266.75	496.67	99.17
T_3	258.16	89.86	292.47	506.67	102.17
T_4	296.70	100.26	336.08	550.00	113.60
T_5	309.31	109.39	350.80	596.67	126.67
T_6	274.92	89.35	309.28	523.33	106.67
T_7	216.84	56.32	245.01	478.33	95.00
CD (0.05)	16.44	5. 24	18.80	58.09	14.03

well documented by several researchers (Lonito *et al.* 2010; Lopez-Bucio *et al.* 2015). Enhancement in uptake of nutrients is reported as a major growth promoting effect (Anil & Lakshmi 2010; Zhang *et al*. 2013; Saravanakumar *et al*. 2013). *Trichoderma* inhibits plant pathogens which helps in overcoming biotic stress, ensuring enhanced crop productivity (Paudel *et al*. 2017). Simultaneous application of *Trichoderma* and AMF is reported to have various positive and synergestic effects on crop growth (Medina *et al*. 2011; Poveda *et al*. 2019). Compatibility of these bio inoculants is revealed from favoured colonisation of *Trichoderma* in the presence of AMF, which in turn helps better nutrient uptake leading to yield improvement.

Economics of crop production

Treatment T_5 was significantly superior in generating higher gross and net returns as well as B:C ratio (Table 7). This was followed by T_4. Based on the results of Experiment I, 12 and 15 kg potting media were on par with respect to ginger production. Hence considering resource and cost effectiveness, 12 kg media can be recommended for grow bag cultivation of ginger. As per the study, micronutrient mixture IISR Power mix G could enhance ginger yields by 11 per cent. INM package of KAU as well as organic crop nutrition were also equally good. Considering the fact that a majority of homestead farmers make use of terraces for cultivation, foliar application of IISR Power mix G could be recommended along with organic nutrition in ginger nutrition schedule.

The results of Experiment II reveal that bio-inoculants AMF and *Trichoderma* conjunctively included in ginger cultivation schedule can enhance the yield. Yield increase of 25 per cent is evident from Table 6. With the application of bioinoculants AMF and *Trichoderma* at planting followed by *Trichoderma* at 30 DAP, 596.67 g fresh ginger was produced $plant^{-1}$, compared to 478.33 g fresh ginger $plant^{-1}$ obtained with

Table 7. Economics of ginger cultivation (Calculated for 200 grow bags)

Treatment	Gross returns (Rs)	Net returns (Rs)	B:C ratio
T_1	6140.00	2893.00	1.89
T_2	5960.00	2692.00	1.82
T_3	6080.00	2783.00	1.84
T_4	6600.00	3280.00	1.99
T_5	7160.00	3817.00	2.14
T_6	5740.00	2683.00	1.75
T_7	6280.00	2543.00	1.79
CD (0.05)	321.92	321.92	0.098

no application of bioinoculants. Based on these two experiments, it could be concluded that 12 kg of potting media is optimum for grow bag grown ginger and multinutrient mixture (IISR Power mix G) when supplemented with the recommended nutrition (organic/integrated) could enhance ginger yields to the tune of 11 per cent. Further enhancement in ginger yield is possible with the use of bioinoculants. AMF and *Trichoderma* when conjunctively used in ginger production could enhance yield up to 25 per cent.

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