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Research Article

Influence of growth retardant and nutrient levels on ginger (*Zingiber officinale Rosc.*) in soilless culture under protected structure

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Abstract

Ginger is an esteemed crop valued for its aromatic and pungent rhizomes. With its wide usage there is an urgent need to go for its cultivation in large scale to meet the demand. Availability of quality planting material and occurrence of pests and diseases are the limiting factors for its cultivation. Thus the present investigation was carried out with an objective to produce quality seed rhizomes in soilless culture under protected structure. Crops under protected structures result in profuse vegetative growth; since rhizomes are of economic concern use of growth retardants have been proven beneficial. Coupled with it is the basic exhaust nature of the ginger crop. Hence experiment was carried out using growth retardant and nutrients of various levels consisting of 12 treatment combinations in total. Of all the treatments, N_3G_2 was found better in terms of growth, yield as well as quality traits. The rhizomes obtained were devoid of pests and diseases. Thus soilless cultivation of ginger under protected structure can be a viable solution to overcome the production constraints.

Keywords: Soilless culture, protected cultivation, nutrients, growth retardant

Introduction

Plant growth and development is often influenced by complex interaction of traits such as soil, climate, variety and the nutrition it receives. Nutrient elements play fundamental role in the physiological activities of plants and primary production of crops is influenced by the availability of nutrients and this in turn depends on distribution and rates of cycling in the soil. It is well known that soilless culture offers an alternative to soil culture when serious soil and water problems like controlled greenhouse may produce crops all along the year without such as, soil borne pests, soil and water salinity, chemical residues in soil, water salinity, lack of fertile soil, water shortage, create difficulties in traditional soil based production. Good quality growing media like cocopeat, vermicompost, perlite that are devoid of disease causing pathogens have been playing an important role for obtaining luxuriant and profused growth in various horticultural crops. The efficiency of the soilless culture system greatly depends on the application design and the way nutrient and water are managed. In addition to this, production of plants in uniform growing environment hampering the growth for higher productivity.

Ginger (*Zingiber officinale* Rosc.) habitually referred to as ginger is a monocotyledon perennial spice that is used worldwide for its aromatic and pungent rhizomes. It is categorized under the family *Zingiberaceae* that is bound with the natural order scitaminae. It is a plant of very ancient cultivation and the spice has long been used in Asia because of its broad spectrum applications. The genus includes about 85 species of aromatic herbs from East Asia and tropical Australia (Bhatt et al., 2013). It is a potent spice valued for its aromatic and pungent rhizome which is a specialized segmented stem structure that grows horizontally just under the soil surface. In the global scenario, India continues to be the largest producer of ginger with an annual production of 11.3 lakh tonnes which is grown from an area of about 1.62 lakh hectares. The major states contributing its production are Karnataka, Kerala, Orissa, Assam, Meghalaya, Arunachal Pradesh and Gujarat which all together account to 65 per cent of the country's total production (Anon. 2019).

Controlling plant size is one of the most important aspects of greenhouse crop production especially where underground part is of economic concern. The use of synthetic growth regulators and chemicals that reduce the growth of the foliage and better partitioning of dry matter in to the rhizome is much emphasized (Maruthi et al., 2003). Growth regulators are also reported to improve yield of many of the crops by suppressing stem elongation and blocking GA production within plants leading to polar transport of carbohydrates from the aerial parts of the plant thereby altering growth and enhancing yield in many root and tuber crops. However the information regarding the use of plant growth regulators and chemicals in ginger crop is very limited. Being propagated through rhizomes, ginger is naturally susceptible to several devastating soil borne plant pathogens especially when conventionally grown as a tropical field crop. It is estimated that seed requirement of ginger at present is 3.3 lakh tonnes and for the year 2025 it is 4.4 lakh tonnes by considering 2 tonnes per hectare seed rate and assuming two per cent area expansion (Prasath et al., 2017). Soilless cultivation of ginger can provide high-quality rhizomes that are free from pesticides and nematodes. There is currently a high demand for year-round supply of quality produce both for seed and consumption purpose. Thus conditioning the production strategies in the protected structures coupled with pathogen free media can be a viable solution to overcome production constraints. Hence, the present investigation was taken up to investigate the influence of growth retardant (Chlorocholine chloride), nutrient levels on the growth, yield and quality components.

Materials and Methods

Morpho-Physiological Parameters

Plant height: Plant height was measured from the base of the plant to the tip of the fully opened youngest leaf of the tallest tiller and is expressed in centimeters.

Number of tillers: The side shoots arising from the basal portion of pseudo stem were counted and expressed as number of tillers per clump.

Number of leaves: Fully opened leaves were counted in the entire clump and expressed as total number of leaves per clump.

Leaf length: The length of leaf was recorded from base of the leaf lamina to the tip of fully opened third leaf from top in tallest tiller of the plant and expressed in centimeters.

Leaf breadth: The breadth of leaf was recorded at widest lamina of fully opened third leaf from top in the tallest tiller of plant and expressed in centimeters.

Pseudostem girth: Pseudo stem girth was measured at basal portion of the shoot by using vernier callipers and mean value was calculated and expressed in millimeters.

Leaf area: Leaf area was calculated using the equation as per Reddy and Reddy (1995) and the values are expressed in square centimeter (cm^2).

LA = LBK

Where, L–Length

B–Breadth

K–Constant Factor (0.666)

Yield and Quality Parameters

Number of primary fingers per clump: Primary fingers arising from the entire clump of rhizomes from each of the labeled plant were counted and average was worked out.

Number of secondary fingers per clump: Number of secondary fingers were counted from all the primary fingers of the whole clump of the rhizomes harvested from a randomly labeled plants and average was worked out.

Length of rhizomes (cm): Rhizomes of randomly labeled clumps from each treatment was measured using the linear scale and mean value was computed.

Width of rhizomes (cm): Rhizomes of randomly labeled clumps from each treatment was measured at the middle of the rhizome and average rhizome width was worked out.

Rhizome yield per plant: Rhizomes were harvested at maturity which was indicated by yellowing and drying of aerial plant parts. Fresh weight of the rhizomes from five randomly selected plants was recorded immediately after harvesting and the average yield per plant was worked out and expressed in grams per plant.

Total rhizome yield: Rhizome yield per hectare area was calculated and expressed in tonnes.

Note: Number of grow bags arranged in 50 square meter area was 360. Further yield calculations were worked out accordingly.

Dry recovery: Hundred grams of fresh rhizomes were dried in an oven until constant weight was obtained. The dry recovery percentage was worked out from the fresh rhizome weight of the sampled plants from the change in their weight after drying in oven. It was calculated using following formula and expressed in percentage.

$$\text{Dry recovery percentage} = \frac{\text{Dry weight of the rhizome after curing (g)}}{\text{Fresh weight of the rhizome (g)}} \times 100$$

Biochemical Parameter (Chlorophyll Content)

The chlorophyll content of fully opened third leaf from top in the tallest tiller of the plant was measured by SPAD meter and the values are expressed as SPAD units.

Quality Parameters

Essential oil: Essential oil content was estimated on fresh weight basis by hydro distillation of freshly harvested rhizomes using Clevenger apparatus (AOAC, 1975). The pre-weighed fresh rhizomes were chopped into small pieces and filled into the round bottom flask. Water was added to cover the rhizomes up to three fourth of the flask and condenser was connected to the apparatus. The operating temperature was set to 60°C. The running water pipe was connected to condenser to keep the condenser cool and help in condensation of vapours into oil droplets. The distillation was continued for three hours till completion of distillation. The essential oil was collected in glass vials and the oil content was estimated using formula.

$$\text{Essential oil (\%)} = \frac{\text{Oil yield (ml)}}{\text{Weight of sample taken (g)}} \times 100$$

Oleoresin: Oleoresin content in the samples was estimated using Soxhlet apparatus per AOAC (1980). Five grams of powdered sample was refluxed with 125ml of acetone. Extraction was continued till the solvent became colourless. Acetone extract of sample was transferred to pre weighed beaker and the solvent was evaporated and weight of the beaker along with extract was recorded. The recovery of oleoresin was expressed in per cent.

$$\text{Crude fibre (\%)} = \frac{(W_2 - W_1)-(W_3 - W_1)}{\text{Weight of sample (g)}} \times 100$$

Incidence of pest and diseases (%): Per cent pest and disease incidence was calculated by using the formula given below

$$\text{Percent pest incidence} = \frac{\text{Number of plants infested}}{\text{Total number of plants}} \times 100$$

$$\text{Percent disease incidence} = \frac{\text{Number of plants infested}}{\text{Total number of plants}} \times 100$$

Results and Discussion

The growth, yield and quality parameters of ginger rhizome recorded showed significant differences among the treatments for growth yield traits (Tab. 1).

Influence of Growth Retardant on Growth and Yield Parameters

The plant height was significantly influenced by different levels of growth retardant and nutrients. Among the various levels of growth retardant used, Control (G3) recorded highest plant height (105.28 cm) as compared to plants treated with CCC @1000 ppm (85.92 cm). Plant height is an important parameter that decides the rhizome growth of ginger. This decrease in plant height might be attributed to the reduction in intermodal length and the inhibition of cell division (Maruthi et al., 2003) as well the anti-gibberlin activity of CCC. These results are in conformity with Sengupta et al. (2008) and Velayutham et al. (2013) in ginger respectively. Parameters like number of tillers/clump (13.21), number of leaves/ clump (312.72), leaf length (25.79 cm) leaf area (12124.95cm^2) were found maximum in the ginger plants sprayed with CCC @1000 ppm followed by CCC @500 ppm and least values were recorded in control. CCC has decisive role in the suppression of apical dominance and diverting the polar transport of auxin towards the basal buds leading to increased tiller production. These findings are in accordance with the reports of Velayutham et al. (2013) and Pariari et al. (2018) in ginger. In contrast the lowest values for leaf (2.25 cm) and pseudustem girth (6.62 mm) were found in plants treated with CCC @1000 ppm and the maximum leaf breadth (2.34 cm) and pseudostem girth (6.78 mm) was recorded in untreated plants.

Rhizome yield parameters like number of primary fingers (9.14), secondary fingers (10.52), length (22.75 cm) and width (10.20 cm) fresh yield of the rhizome (44.55 t/ha) were highest in plants treated with CCC @1000 ppm and the minimal value was recorded in control. The effect of CCC on suppressing vegetative growth might have resulted in better utilization of carbohydrates and its effective translocation resulted in more number of primary and secondary rhizomes per plant and the CCC might have enhanced the translocation of carbohydrates to the developing sink and contributed for better enlargement of rhizomes. The highest yield might be due to positive influence on yield contributing characters like leaf area, number of tillers per clump etc. Chlorocholine Chloride (CCC) is a quaternary ammonium compound which inhibits the Copalyl Diphosphate Synthase (CDPS) and Kaurene Synthase (KS) in the GAs biosynthetic pathway leading to translocation of photoassimilates from the vegetative part to the underground rhizomes.

The rapid proliferation of xylem parenchyma, formation of storage rhizomes and production of more number of rhizomes would have helped in increasing the yield. These experimental findings are in consonance with the findings of Velayutham et al. (2013) in ginger.

Influence of nutrient levels on growth and yield parameters

Plant height was significantly influenced by nutrient application. Maximum plant height was found in N_3 at 180 DAP (97.82 cm). Although plant height is a genetically controlled character, it can be modified by the application of fertilizers which indicates that nutrient elements in proper doses increased the plant height. Nitrogen and phosphorous are critical determinants of plant growth and productivity and both plant growth and root morphology are important parameters for evaluating the effects of supplied nutrients. The amount and timing of N application can also alter plant morphology, nutrient availability, and net photosynthesis. Phosphorus (P) is considered a primary nutrient for plant growth and is needed to sustain optimum crop production and quality. The element is essential for cell division, reproduction and plant metabolism; moreover, its role is related to the acquisition, storage, and use of energy. In addition, P plays an important role in lateral root morphology and root branching and influences not only root development, but also the availability of nutrients. Similar results have been obtained by Yousuf et al. (2019) in ginger. The least plant height was noticed in N_4 (88.20 cm) which might be due to the imbalance of nutrients due to excess application. Number of tillers/clump (13.56), number of leaves/clump (329.73), leaf length (25.34 cm) and leaf area (13062.59 cm^2), were found maximum in N_3 with 180% of RDF + 180% Secondary nutrients + Micronutrients. The increase in number of tillers could be due to its marked influence on the capacity of plants to absorb and utilize optimum amount of Nitrogen in buildup of plant tissue and vegetative growth (Ojikpong. T. and Undie U. L., 2019). This can also be attributed to the rapid conversion of synthesized carbohydrates into protein and consequently the increase in number and size of growing cells, resulting ultimately in increased number of tillers. Thus the

Table 1. Influence of nutrients, growth retardant and their interaction on growth attributes.

Treatments	Plant height (cm)	Number of tillers/ clump	Number of leaves/ clump	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm^2)	Pseudostem girth (mm)
Growth retardant (G)							
G1: CCC @500 ppm	89.28	13.18	290.17	24.89	2.30	11065.86	6.64
G2: CCC @1000 ppm	85.92	13.21	312.72	25.79	2.25	12124.95	6.62
G3: Control	105.28	12.16	296.24	23.58	2.34	10905.21	6.78
S.Em ±	0.52	0.05	1.25	0.17	0.01	92.18	0.01
CD @1%	2.05	0.20	4.94	0.65	0.03	364.54	0.05
Nutrients (N)							
N_1	93.33	13.36	284.11	23.97	2.32	10512.44	6.63
N_2	94.62	13.04	305.77	25.32	2.28	11767.43	6.77
N_3	97.82	13.56	329.73	25.34	2.35	13062.59	6.60
N_4	88.20	11.97	279.23	24.39	2.23	10118.89	6.77
S.Em ±	0.60	0.06	1.44	0.19	0.01	106.43	0.01
CD @1%	2.37	0.23	5.70	0.75	0.03	420.94	0.06
Interaction (GXN)							
N_1G_1	89.07	13.10	270.00	23.57	2.35	9941.62	6.57
N_1G_2	85.60	13.50	287.33	24.80	2.29	10884.68	6.57
N_1G_3	105.33	13.47	295.00	23.53	2.32	10711.02	6.75
N_2G_1	90.73	13.56	300.13	25.50	2.26	11536.92	6.80
N_2G_2	85.00	13.53	320.67	26.20	2.22	12438.71	6.73
N_2G_3	108.13	12.07	296.50	24.27	2.36	11326.66	6.77
N_3G_1	91.60	13.30	312.87	25.33	2.36	12483.00	6.50
N_3G_2	91.60	14.50	350.87	26.57	2.30	14274.10	6.50
N_3G_3	110.27	12.87	325.47	24.13	2.38	12430.68	6.79
N_4G_1	85.73	12.77	277.68	25.17	2.21	10301.89	6.80
N_4G_2	81.47	11.83	292.01	25.60	2.19	10902.32	6.70
N_4G_3	97.40	11.30	268.00	22.40	2.29	9152.46	6.80
S.Em±	1.04	0.10	2.50	0.33	0.01	184.35	0.02
CD @1%	4.11	0.40	9.88	1.31	0.05	729.08	0.10

Note: RDF (Recommended Dose of Fertilizers) of 140:70:70 kg/ha of NPK-for soilless culture. Secondary Nutrients-Ca, Mg and S @35 kg/ha, Micronutrients: commercial formulation–5 kg/ha. Growth retardant CCC (Chlorocholine Chloride) was used as foliar spray.

positive effect of nutrients on growth parameters might be due to the functional role of nutrients in plant growth. Pseudostem girth was maximum in N_4 and N_2 (6.77 mm each) whereas minimum in N_3(6.60 mm).

Yield attributes like number of primary (9.56) and secondary fingers per clump (10.91), length of rhizomes (23.22 cm), width of rhizomes (10.64 cm) and fresh rhizome yield (48.69 t/ha) were highest N_3. Linear response was evident in plant growth for increased level of nutrition till level N_3, which can be attributed to the basic exhaust nature of ginger crop. The increase in number of mother and finger rhizomes per plant resulting from nutrient application may be ascribed to its imperative role in plant growth in general, and tissue differentiation in particular. The findings are in agreement with that reported by Marschner, 2002 in turmeric. The higher average rhizome yield could be due to more luxuriant growth, more foliage and higher supply of photosynthates which helped in producing bigger rhizomes, hence resulting in higher yields.

Growth and yield parameters as influenced by interaction of growth retardant and nutrients

Considering the interaction, N_3G_3 (110.27 cm) recorded maximum plant height and the least was found in N_4G_2 (81.47 cm). Traits like leaf length (26.57 cm), leaf area (14274.10 cm^2), number of leaves per clump (350.87), number of tillers (14.50), were found to be highest in combination N3G2 (180% of RDF + 180% Secondary nutrients + Micronutrients and CCC @1000 ppm) and least was recorded in N_4G_3. This might be due to availability of nutrients in balanced state because of split application of nutrients through fertigation and also anti-gibberlin activity of CCC might have helped in reduction in internodal length and increased number of tillers per clump.

Yield attributing characters followed the same trend. Traits like number of primary fingers (9.70) and secondary fingers (11.60), length (24.00 cm) and width of rhizomes (11.37 cm) fresh rhizome yield (49.60 t/ha) were maximum in N_3G_2 (180% RDF + 180% Secondary nutrients and micronutrients and CCC @1000 ppm). Rhizome yield was on par with N_3G_1 (48.14 t/ha). Application of CCC @1000 ppm was significantly superior over control and higher levels of nutrients at N_3 under protected conditions have favored increase in leaf number, leaf area, and number of leaves and DMP (Dry Matter Production) which might have resulted in higher yield.

Biochemical parameter as influenced by growth retardant, nutrients and their interaction

Among the treatment combinations, N_3G_2 (180% RDF + 180% Secondary nutrients and micronutrients and CCC @1000 ppm) resulted in higher chlorophyll content (Fig. 1). CCC is known for its promotion of intense chlorophyll formation, increased photosynthesis and strengthening of stems. CCC has been found to increase the Ribulose Bisphosphate Carboxylase (RuBisCO) activity, that in turn helps in enhancing the photosynthetic capacity (Wang and Xiao, 2009). Proper amount of nutrients might have resulted in increased photosynthesis resulting in higher chlorophyll content.

Quality parameters as influenced by growth retardant, nutrients and their interaction

Influence of growth retardant and nutrients on quality attributes is depicted in Fig. 2. Highest essential oil content (1.40%), oleoresin content (10.20%) and crude fibre content (4.70%) were noticed in N_3G_2 (180% RDF + 180% Secondary nutrients + Micronutrients and CCC @1000 ppm). Secondary metabolites are known to be produced in higher concentration in plants during stress conditions. The growth retardant CCC by blocking the biosynthesis of gibberlin would have brought about artificial stress condition in plants, thereby improving the oil and oleoresin contents. The ability of CCC to block the biosynthesis of gibberellins (Pariari et al., 2018) and

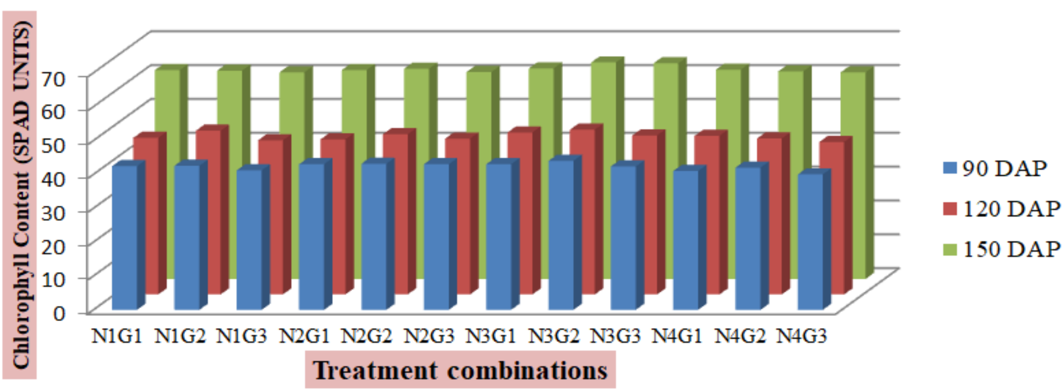

Figure 1. Chlorophyll content as influenced by different treatment combinations.

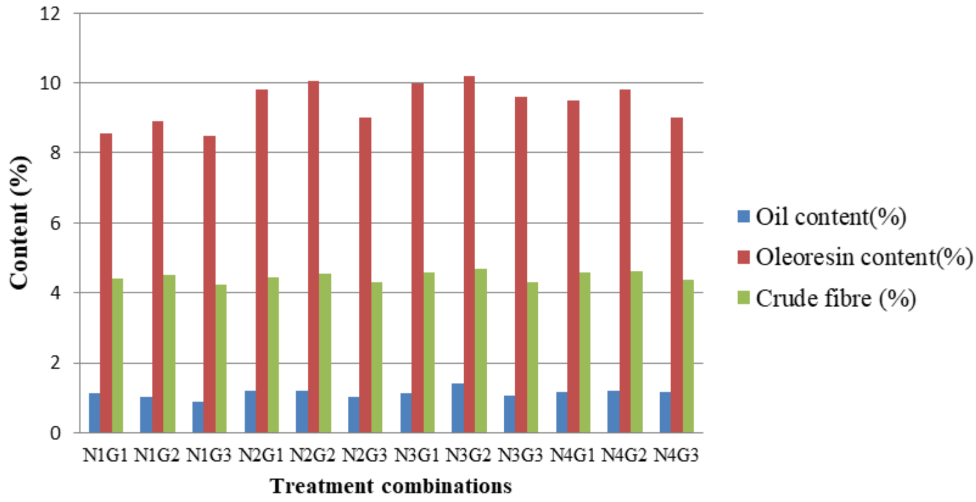

Figure 2. Essential oil, oleoresin and crude fibre contents as influenced by different treatments.

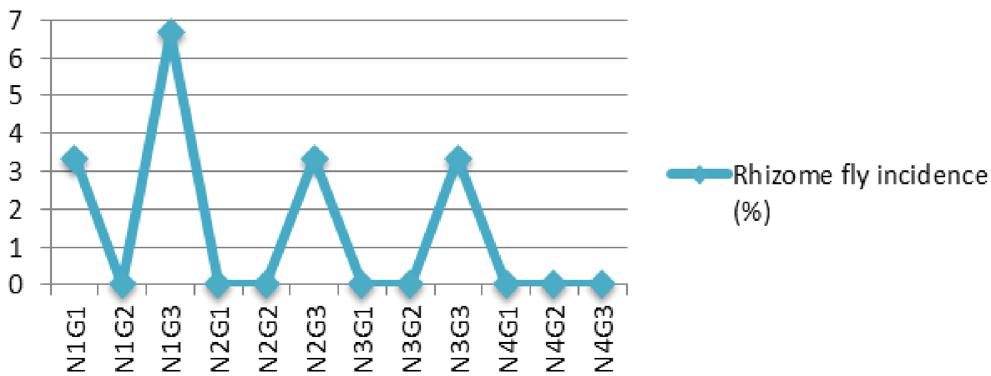

Figure 3. Pest and disease occurrence during the study period.

the efficient source and sink relationships by CCC may be responsible for increasing the oil and oleoresin content (Ullah and Bano., 2011). Sufficient amount of nutrients and thickening of fibre cells with advancing maturity would have resulted in more crude fibre content in the treatment.

Pest and disease occurrence during the study period

Except for rhizome fly, no incidence of other pest was recorded in plants. The plants were free from any disease infection. Ginger rhizomes are usually affected by soil borne various soil borne pathogens. Since the growing medium was devoid of soil and was sterile the rhizomes were free from any pathogen infection (Fig. 3).

Conclusions

Experimental results indicated that growth retardant CCC and different levels of nutrient application had significant impact on ginger in soilless culture under protected structure. Best treatment combination in the study was N_3G_2 (180% RDF + 180% Secondary nutrients + Micronutrients and CCC @1000 ppm). A better amount of coco peat (75%) and less amount of sand (25%) favoring clean culture coupled with which in turns increased the growth and yield thereby enhancing crop growth and yield. The idea of soilless cultivation has been perceived to overcome the field problems. It also helps in offseason production making the fresh rhizomes available throughout the year as well as, obtaining disease free and quality rhizomes thus meeting the prerequisite for seed purpose. In addition to the above advantages, it also helps in reducing the frequency of application of plant protection chemicals by clean culture due to exclusion of soil as media.

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