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Effect of Spacing on Growth and Yield Performance of *Zingiber officinale* Rosc. in Vertisols of Chhattisgarh

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ABSTRACT

Zingiber officinale Rosc. was cultivated at three plant spacing *viz;* S-1 (30 x 20cm), S-2 (30 x 25cm) and S-3 (30 x 30cm) in vertisols at research farm of IGKV, Raipur (C.G.) in 2018-19. The soil was found very rich in organic matter and other nutrients *i.e.,* 0.67% organic carbon, 166.2 kg N ha^{-1}, 9.7 kg P ha^{-1} and 544.8 kg k ha^{-1}. The PAR was recorded in ginger crop in range of 187.69-1003.63 µmol s^{-1} m^{-2}. The average temperature was recorded in range of 23.65-32.65 °C. The average relative humidity was recorded in range of 36.00-96.00 %. However impact of crop spacing on yield of highest fresh weight of ginger was received 26.97 q ha^{-1}in S-2 (30x25cm) spacing as compare to S-1 (24.58 q ha^{-1}) and S-3 (14.82 q ha^{-1}). The minimum fresh weight yield of ginger received in S-3 (30x30cm) spacing.

Key words *: Growth, Yield, Vertisols, Spacing*

Introduction

Zingiber officinale is a subtropical plant grown for its root (rhizome or underground stem). The root has tan skin, ivory to pale green flesh, peppery, slightly sweet flavor. Ginger has many medicinal uses; the fresh or dried rhizome is used in oral or topical preparations for the treatment a variety of ailments, while the essential oil is applied topically as an analgesic. Evidence suggests that ginger is most effective against nausea and vomiting in small quantity, associated with surgery, vertigo, travel sickness and morning sickness and pregnancy, and cancer chemotherapy (Bone *et al*., 1990; Grontved *et al*., 1988, Sripramote *et al*., 2003).

Zingiber officinale Rosc. is a spice and medicinal plant belonging to the Zingiberaceae family. Ginger has long been used in folk medicine in India and China. Especially, the wet and dry root of ginger is widely used in the medicine and food industry (Jabborova and Egamberdieva, 2019). It has been used in folk medicine for colds, sore throats, asthma, and joint pain and stimulates appetite Ginger is also rich in beneficial nutrients for example phosphorus, potassium, and calcium, which play important roles in human physiological processes. These substances play an important role in boosting human immunity and maintaining health (Jabborova *et al.,* 2021; Zadeh and Kor, 2014). The dry rhizome of ginger is and contains biologically active compounds. The rhizome contains carbohydrates, fats, proteins, vitamins, minerals, amino acids, monoterpenoids (camphene, sineiol, borneol, citral curcumin, and linalool), gingerol, and sesquiterpenoids.

The spice ginger is one of the most widely used species of the family Zingiberaceae. It is a common condiment for various foods and beverages (Jabborova *et al.,* 2021). Both fresh and dried ginger

rhizomes are used worldwide as a spice, and ginger extracts are used extensively in the food, beverage, and confectionery industries (Jabborova and Egamberdieva, 2019; Zingiber officinale, 2010). It is also chiefly used medicinally for indigestion, stomachache, malaria, fevers, common cold, and motion sickness. Besides being a key ingredient in many world cuisines and food processing industry, ginger possesses anti-carcinogenic, antioxidant, and antiinflammatory properties (Zhao *et al*., 2016; Grzanna *et al*., 2005).

Materials and Methods

The study was conducted at research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) in Vertisols. Field was prepared as per recommended practice with application of 10 t ha^{-1} FYM and bund/ ridges were made at the distance of 30 cm. The plot size was kept of 2 x2m for three spacing treatment *viz;* 30 x 20cm (S1), 30 x 25cm (S2) and 30 x 30cm (S3) with three replications and accordingly the seeds of ginger(Var-Suprabha) was sown with basal dose of NPK followed by split doses @ 120N, 60P and 60K kg ha^{-1} in form of Urea, SSP and Murate of Potash as recommended.

All the regular operations like weeding, irrigation and disease irradiations were made during the growth period of crop. Growth behaviour of ginger crop for all the treatment was observed for yield parameters of rhizomes after harvesting at maturity stage.

Micro-climatic features *viz;* PAR (µmol s^{-1} m^{-2}), Temperature (^oC) and relative humidity (%) available to crop were measured during cropping period.

This Kanhar soil of the site are characterized by fine texture, sticky nature and itshowed 20-30 % sand, 20-30% silt and >45% clay with wilting point of 20.20cm. The soil EC and pH was found 0.30 (ds/m) and 7.4-7.6 pH respectively. Since it is Vertisols, therefore possesses very rich in organic matter and other nutrients *i.e.*, 0.67% organic carbon, 166.2 kg N ha^{-1}, 9.7 kg P ha^{-1} and 544.8 kg K $ha^{-1}$are presented in Table 1 (Harne 2013).

Table 1. Soil components in study area

Soil parameters	Value
Physical structure	
Sand (%)	20-30
Silt (%)	20-30
Clay (%)	>45
Wilting point (cm)	20.20
EC (ds/m)	0.30
pH	7.4-7.6
Organic carbon (%)	0.67
Av. Nitrogen (Kg ha^{-1})	166.2
Av. Phosphorus (Kg ha^{-1})	9.7
Av. Potassium (Kg ha^{-1})	544.8

Reference : Harne (2013)

Results

Micro-climatic conditions

PAR, Temperature and Relative Humidity are recorded at 15 day interval during crop growing period *i.e.* July 2018 to January 2019 and data are presented in Table 2.

Photosynthetically Active radiation (PAR µmol s^{-1} m^{-2})

The PAR was recorded in ranges of 187.69 to 657.92, 275.61 to 919.99 and 519.92 to 1003.63 µmol s^{-1} m^{-2} during July to August, September to November and December to January respectively. The maximum PAR was recorded in the month of January (1003.63 µmol s^{-1} m^{-2}) and minimum PAR was recorded in the month of July (187.69 µmol s^{-1} m^{-2}). In rainy season July to August PAR was recorded less as compare to September to November and December to January (Table 2).

Temperature (^oC)

The average temperature was recorded in ranges of 27.80 to 31.62^oC, 29.93 to 32.85^oC and 23.65 to 28.00^oC during July to August, September to November and December to January respectively. The maximum temperature was recorded in the month of October (32.85 ^oC) and minimum temperature was recorded in the month of January (23.65 ^oC) (Table 2).

Relative Humidity (%)

The average relative humidity was recorded in ranges of 77.75 to 96.00%, 38.17 to 81.33% and 36.00 to 57.75% during July to August, September to November and December to January respectively. The maximum relative humidity was recorded in the month of July (96.00%) and minimum relative humidity was recorded in the month of January (36.00%) (Table 2).

Table 2. Micro-climatic conditions available to the crop during July 2018 to Jan. 2019

Date of Observation	PAR (µmol S^{-1} m^{-2})	Temp. (°C)	RH(%)
1st July 2018	657.92 ±56.92	31.62 ±0.15	77.75 ±1.17
15th July 2018	187.69 ±1.69	27.80 ±0.00	96.00 ±0.00
15th Aug 2018	326.89 ±117.57	30.14 ±0.77	86.83 ±0.69
1st Sept 2018	327.92 ±111.07	29.93 ±0.10	81.33 ±1.12
15th Sept 2018	919.99±93.37	31.95±0.17	63.50±0.19
1st Oct 2018	671.74±97.40	32.85±0.28	57.42±1.03
15th Oct 2018	275.61±67.98	32.21±0.34	48.33±0.47
1st Nov 2018	836.09±162.04	32.69±0.37	51.58±1.62
15th Nov 2018	861.04±155.87	31.38±0.20	38.17±0.19
1st Dec 2018	519.92±12.87	28.00±0.26	48.67±0.47
15th Dec 2018	912.66±133.96	24.78±0.64	57.75±2.39
1st Jan 2019	1003.63±62.28	23.65±0.59	36.00±1.05
15th Jan 2019	839.33±72.69	26.32±0.43	38.67±0.77

Table 3. Effect of spacing on growth of ginger crop

Spacing (cm)	Numbers of tillers	Crop Height (cm)	Collar Diameter (mm)	Leaves		
				Number	Length (cm)	Width (cm)
S1 (30x20)	9.16±1.91	42.64±6.33	6.43±0.87	115.41±25.10	14.79±0.84	1.36±0.05
S2 (30x25)	11.42±1.26	42.29±3.79	6.20±0.18	160.67±20.43	14.09±0.74	1.32±0.03
S3 (30x30)	8.66±2.13	39.34±2.05	5.65±0.32	105.75±45.05	13.63±0.18	1.31±0.06

Growth performance of Ginger

The effect of spacing on ginger crop on growth parameters of ginger crop is presented in Table 3 for numbers of tillers; plant height and collar diameter; number of leaves and its length and width.

Number of tillers

The maximum average number of tillers of ginger crop was observed 11.42 $plant^{-1}$ in S-2(30x25 cm) followed by 9.16 and 8.66 $plant^{-1}$ in S-1 (30x20 cm) and S-3 (30x30 cm) respectively. The highest number of tillers was observed in S-2 and less number of tillers $plant^{-1}$ observed in S-3 spacing (Table 3).

Crop height (cm)

The maximum average crop height of ginger was observed 42.64cm in S-1 (30x20cm) followed by 42.29cm and 39.34cm in S-2 (30x25cm) and S-3 (30x30cm) respectively. The highest average crop height was observed in S-1 and less crop height was observed in S-3 spacing (Table 3).

Collar diameter (mm)

The maximum average collar diameter of ginger was observed 6.43mm in S-1 (30x20cm) followed by 6.20mm and 5.65mm in S-2 (30x25cm) and S-3 (30x30cm) respectively. The highest average collar diameter was observed in S-1 and minimum collar diameter was observed in S-3 spacing (Table 3).

Number of Leaves

The maximum average number of leaves of ginger was observed 160.67 in S-2 (30x25cm) followed by 115.41 and 105.75 in S-1 (30x20cm) and S-3 (30x30cm) respectively. The highest average number of leaves was observed in S-2 and minimum number of leaves was observed in S-3 spacing (Table 3).

Leaves length (cm)

The maximum average leaves length 14.79cm in S-1 (30x20cm) followed by 14.09cm and 13.63cm in S-2 (30x25cm) and S-3 (30x30cm) respectively. The highest average leaves length was observed in S-1 and minimum leaves length was observed in S-3 spacing (Table 3).

Leaves width (cm)

The maximum average leaves width 1.36cm in S-1 (30x20cm) followed by 1.32cm and 1.31cm in S-2 (30x25cm) and S-3 (30x30cm) respectively. The highest average leaves width was observed in S-1 and minimum leaves width was observed in S-3 spacing (Table 3).

Growth of rhizomes

The effect of spacing on growth of rhizome of ginger crop is presented in Table 4 for mother rhizome length and width, Number of prime finger and its length and width, Number of sub-finger and its length and width.

Mother rhizome length (cm)

The maximum average mother rhizome length of ginger was observed 4.53 cm in S-3 (30x30 cm) followed by 4.33cm and 4.25 cm in S-1 (30x20 cm) and S-2 (30x25 cm) respectively. The highest average mother rhizome length was observed in S-3 and less mother rhizome length was observed in S-2 spacing (Table 4).

Mother rhizome width (cm)

The maximum average mother rhizome width of ginger was observed 2.94 cm in S-1 (30x20 cm) followed by 2.92 cm and 2.55 cm in S-2 (30x25 cm) and S-3 (30x30 cm) respectively. The highest average mother rhizome width was observed in S-1 and less mother rhizome width was observed in S-3 spacing (Table 4).

Number of prime finger

The maximum average number of prime finger of ginger was observed 2.20 in S-2 (30x25 cm) followed by 2.15 and 2.00 in S-1 (30x20 cm) and S-3 (30x30 cm) respectively. The maximum average number of prime finger was observed in S-2 and minimum number of prime finger was observed in S-3 spacing (Table 4).

Number of sub-finger

The maximum average number of sub-finger of ginger was observed 7.90 in S-2 (30x25 cm) followed by 6.40 and 5.10 in S-1 (30x20 cm) and S-3 (30x30 cm) respectively. The maximum average number of sub-finger was observed in S-2 and minimum number of sub-finger was observed in S-3 spacing (Table 4).

Prime finger length (cm)

The maximum average prime finger length of ginger was observed 6.60 cm in S-2 (30x25 cm) followed by 5.84 cm and 5.82 cm in S-1 (30x20 cm) and S-3 (30x30 cm) respectively. The highest average prime finger length was observed in S-2 and less prime finger length was observed in S-3 spacing (Table 4).

Prime finger width (cm)

The maximum average prime finger width of ginger was observed 4.14cm in S-2 (30x25 cm) followed by 3.91cm and 3.55cm in S-1 (30x20 cm) and S-3 (30x30 cm) respectively. The highest average prime finger width was observed in S-2 and less prime finger width was observed in S-3 spacing (Table 4).

Sub-finger length (cm)

The maximum average sub-finger length of ginger was observed 2.57cm in S-2 (30x25 cm) followed by 2.10 cm and 1.95 cm in S-1 (30x20 cm) and S-3 (30x30 cm) respectively. The highest average sub-finger length was observed in S-2 and less sub-finger length was observed in S-3 spacing (Table 4).

Sub-finger width (cm)

The maximum average sub-finger width of ginger was observed 1.72 cm in S-2 (30x25 cm) followed by 1.55 cm and 1.43 cm in S-1 (30x20 cm) and S-3 (30x30 cm) respectively. The maximum average sub-finger width was observed in S-2 and minimum sub-finger width was observed in S-3 spacing (Table 4).

Yield (q ha^{-1})

Effect of spacing on ginger crop onyield of ginger *viz.*, fresh weight and oven dry weight of ginger is presented in Table 4.

Fresh weight

The maximum yield of gin-

Table 4. Effect of spacing on growth and yield of rhizome in ginger crop

Spacing (cm)	Mother rhizome		No. of Fingers		Prime fingers		Sub-fingers		Yield (q ha^{-1})	
	Length (cm)	Width (cm)	Prime finger	Sub-finger	Length (cm)	Width (cm)	Length (cm)	Width (cm)	Fresh	Oven dry
S1 (30x20)	4.33±0.51	2.94±0.26	2.15±0.34	6.40±1.43	5.84±0.63	3.91±0.68	2.10±0.28	1.55±0.14	24.58±3.61	6.03±0.89
S2 (30x25)	4.25±0.70	2.92±0.55	2.20±0.69	7.90±3.08	6.60±1.26	4.14±0.97	2.57±0.64	1.72±0.31	26.97±3.84	6.78±0.97
S3 (30x30)	4.53±0.59	2.55±0.37	2.00±0.16	5.10±1.37	5.82±0.56	3.55±0.53	1.95±0.22	1.43±0.19	14.82±1.28	3.69±0.32

ger was recorded 26.97 q ha^{-1} in S-2 (30x25 cm) followed by 24.58 q ha^{-1} and 14.82 q ha^{-1} in S-1 (30x20 cm) and S-3 (30x30 cm) respectively. The highest yield was recorded in S-2 and minimum yield was recorded in S-3 spacing (Table 4).

Oven dry weight

The maximum oven dry yield of ginger was recorded 6.78 q ha^{-1} in S-2 (30x25 cm) followed by 6.03 q ha^{-1} and 3.69 q ha^{-1} in S-1 (30x20cm) and S-3 (30x30 cm) respectively. The highest oven dry yield was recorded in S-2 and minimum oven dry yield was recorded in S-3 spacing (Table 4).

Discussion

PAR, Temperature and Relative humidity recorded at 15 days interval during crop period PAR was measure crop in range of 187.6-1003.6 µmol s^{-1} m^{-2}. The average temperature was measuredin crop range of 23.65-32.85 °C. The average relative humidity was recorded in crop range of 36.00-96.00 %. Similar results of micro-climatic conditions were recorded by Dindekar (2012), Harne (2013) and Naugraiya (2003-2013) during cultivation of various Rabi and Kharif crops.

The count of number of tillers was more in ginger crop, this might be due to higher sun light intensity and duration in field reflecting the initiation of more tillers. Kandiannan *et al.* (1999) recorded insignificant variation in population of tiller in ginger plant, grown alone and with maize.

The vegetative growth of ginger *viz.,* height, collar diameter, leaves number, leaves length and width are more or less higher in S-2 Spacing as compare to two another spacing. Similar result found on Melati *et al.* (2015) growth of large white ginger grown in the same pattern, increasing rapidly. Attoe and Osodeke (2009) attributed the increase in height of *Z. officinale* to increaseto use N application.The active phase of vegetative growth on the plant life is after planting, a phase when most activities are allocated to plant vegetative growth Li *et al.* (2010).

The plant spacing showed significant yield at closer spacing which may be ascribed to higher density of plant per unit area with efficient utilization of nutrients, ultimately produced 20.17 to 22.4 q ha^{-1} rhizomes. Such results were narrated by Gosh and Hore (2011), Yadav *et al.* (2013) for ginger and Mohamed *et al.* (2014) for turmeric.

Fresh weight yield of ginger was highest in S-2 spacing it might be due to in 30x25 cm spacing is good for ginger cultivation. Ginger prefers warm and humid climate and it grow well in medium light intensity (Zhenxian *et al*., 2000). Similar pattern of oven dry yield of ginger was recorded higher in S-2 spacing.Akinyemi *et al.* (2014) reported on the improved growth and yield in response to fertiliser application of ginger.

Conclusion

The present Study demonstrates that growth and yield parameters *viz;* mother rhizome length and width, number of prime finger and its length and width and number of sub-finger and its length and width are better in spacing S-2 (30x25 cm) as compare to other S-1 (30x20cm) and S-3 (30x30cm) spacing, where growth and yield of rhizomes of ginger crop was found better for spacing 30 x 25 cm with 26.97q ha^{-1} (F wt) as compare to 30x20 cm and 30x30 cm (14.82 q ha^{-1}).

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