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Integrated strategy to control wilt disease of cumin (*Cuminum cyminum* L.) caused by *Fusarium oxysporum* f. sp. *cumini* (Schlecht) Prasad & Patel

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Abstract

Various fungicides, oilcakes and fertilizers were evaluated at Jaipur (Rajasthan) for the management of cumin (*Cuminum cyminum*) wilt caused by *Fusarium oxysporum* f. sp. *cumini*. Trimethyl thiuram disulphide (0.1 g g^{-1} seeds) was the best fungicide which was on par with propiconazole, carbendazim and copper oxychloride (0.1 g g^{-1} seeds) for the control of wilt. The disease incidence was minimum under the soil treatment with neem cake (30 q ha^{-1}) which was on par with sesamum cake (25 q ha^{-1}). Among the chemical and non-chemical manures, application of NPK @ 40 kg ha^{-1} was most suitable to control the disease which was on par with *Azotobacter* @ 40 kg ha^{-1}. The disease incidence was also significantly lower in plants grown in solarized soil. The yield was significantly higher in all treatments as compared to control. The highest cost : benefit ratio was obtained (1:40) in thiophanate methyl treatment followed by carbendazim. Among the combined treatments, minimum disease incidence was recorded with solarized soil + sesamum cake @ 25 q ha^{-1} + seed treatment with carbendazim @ 0.1 g g^{-1} seeds followed by solarized soil + sesamum cake @ 25 q ha^{-1} + *Azotobacter* @ 40 q ha^{-1}. However, the highest cost : benefit ratio (1:10.6) was obtained with solarized soil + sesamum cake @ 25 q ha^{-1} + *Azotobacter* (biofertilizer) @ 40 kg ha^{-1}. The integrated treatments recorded the highest grain yield and low disease incidence over control as compared to individual application.

Keywords: cumin, *Cuminum cyminum*, *Fusarium oxysporum* f. sp. *cumini*, wilt management.

Introduction

Cumin wilt caused by *Fusarium oxysporum* f. sp. *cumini* L. results in yield losses up to 35% in cumin (*Cuminum cyminum* L.) in some districts of Rajasthan (Vyas & Mathur 2002). Seed treatment and soil application of chemicals is the conventional practice adopted for controlling cumin wilt. Soil application of neem, cotton, castor and mustard cakes in combination with seed treatment with chemicals are also adopted for the control of cumin wilt. Since the pathogen *F. oxysporum*

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f. sp. *cumini* is seed as well as soil borne in nature, an integrated disease management strategy was evaluated for the control wilt of cumin.

Materials and methods

The field trials were conducted at Department of Botany, University of Rajasthan, Jaipur (Rajasthan) during *rabi* 2004 and 2005 in a randomized block design with three replicates with variety RZ-19. The soil of the experimental field was slightly alkaline in reaction, poor in nitrogen, phosphorus and sulphur but moderate in potassium, having low moisture retention capacity. Each treatment was replicated thrice in 2 m x 3 m plots. Ten day old culture of *F. oxysporum* f. sp. *cumini* (grown on PDA medium) was transferred to sterilized sorghum seeds in 250 ml flasks and cultured for 7 days. The cultures were ground in mixer-grinder and specific quantity of inoculum was mixed with soil before sowing the seeds in the field. Sowing was done during the last week of November during each crop season. The seeds were then treated with dry fungicides (thiophanate methyl, propiconazole, trimethyl thiuram disulphide, carbendazim, copper oxychloride, mancozeb, captaf and dinitrophenyl crotonate) (0.1 g g^{-1} seeds) by thorough mixing. A check was maintained along with the treatments. For soil solarization the ploughed, dry soil was mulched with transparent polyethylene sheet (2.5 m thickness) during summer; un-mulched soil served as control. NPK used in the experiment had a mixture of ammonium nitrate, single super phosphate and muriate of potash in 15:15:15 ratio and applied at four levels (10, 20, 30 and 40 kg ha^{-1}). Similarly, four levels (10, 20, 30 and 40 kg ha^{-1}) of *Azotobacte*r and four levels (10, 20, 30 and 40 q ha^{-1}) of vermicompost were applied in soil, before sowing. A plot without fertilizers served as control. The oil cakes (mustard cake, neem cake, cotton cake, sesame cake and groundnut cake) were finely powdered and thoroughly mixed with soil before 25 days of sowing at 15, 20, 25 and 30 q ha^{-1} each. The per cent disease incidence (PDI) and yield was recorded at final harvest stage.

$$\text{Per cent disease incidence (PDI)} = \frac{\text{Total no. of wilt affected plants}}{\text{Total no. of plants observed}} \times 100$$

Results and discussion

Among the fungicides, trimethyl thiuram disulphide (0.1 g g^{-1} seed) was the best treatment to control the disease incidence (PDI 35.02%) which was on par with copper oxychloride, carbendazim and propiconazole (0.1 g g^{-1} seed). Maximum yield was observed under the treatment copper oxychloride at all concentrations (Table 1). Champawat & Pathak (1991) reported that seed treatment with carbendazim and benomyl gave the best disease control and increased yield. Ghasolia & Jain (2004) also observed that carbendazim (0.2%) showed reduced pre-and post-emergence seedling mortality (8%-10%) and gave increased seed germination and vigour index. Bardia & Rai (2007) concluded that fungicides with bio-agents significantly reduced wilt disease incidence and increased the yield in cumin.

Among the oil cakes, lowest disease severity (31.05 PDI) was recorded under soil treatment with neem cake (30 q ha^{-1}) which was on par with sesamum cake (25 q ha^{-1}) (Table 2). Diyora & Khandar (1995) reported that mustard cake followed by groundnut cake was the most effective organic amendment for managing cumin wilt in pot culture. Mawar & Lodha (2002) observed that the combined effect of *Brassica* amendments (2.5 t ha^{-1}) and summer irrigation was very effective to control wilt disease of cumin in the field. Neem cake at 0.5% to 5.0% and mustard cake at 0.5% and 2.0% levels were reported to be stimulatory for the vegetative growth of *F. oxysporum* f. sp. *lini* and *F. oxysporum* f. sp. *udum* (Singh & Singh 1970). Among the inorganic and organic fertilizer treatments, application of NPK @ 40 kg ha^{-1} was the most suitable to control wilt disease severity (PDI 31.23%) which was on par with *Azotobacter*

Table 1. Effect of seed treatment with various fungicides on wilt disease incidence and yield of cumin

Fungicide	Quantity (g g^{-1} seed)	Per cent disease incidence			Yield (kg ha^{-1})			Net cost (Rs ha^{-1})	Benefit (Rs ha^{-1})	C:B ratio
		2004-05	2005-06	Pooled	2004-05	2005-06	Pooled			
Thiophanate methyl	0.1	40.20	40.17	40.18	284.00	291.75	287.87	352	14,393	1:40
Propiconazol	0.1	41.86	37.98	39.92	280.00	295.25	287.62	450	14,381	1:31
Trimethyl thiuram disulphide	0.1	38.12	31.93	35.02	312.75	311.75	312.25	570	15,612	1:27
Carbendazim	0.1	41.53	37.71	39.62	294.75	295.25	295.00	435	14,750	1:33
Copper oxychloride	0.1	38.89	39.53	39.21	315.25	349.75	332.50	745	16,625	1:22
Mancozeb	0.1	45.95	43.03	44.49	224.00	241.25	232.62	650	11,631	1:17
Captaf	0.1	50.50	42.07	46.28	230.00	240.75	235.37	440	11,768	1:26
Dinitrophenyl crotonate	0.1	49.29	42.80	46.04	231.25	242.50	236.87	548	11,843	1:21
Control		56.87	51.08	53.97	107.0	115.25	111.37			
Sem±		0.45	1.20	1.50	1.62	0.91	8.51			
CD (P=0.05)		3.51	4.35	6.97	18.94	12.75	23.42			

Net cost=Cost of cultivation + Labour charge + Rental value of instruments; Sale price of produce during 2004-06=Rs. 50 kg^{-1}

Table 2. Effect of soil treatment with various oil cakes on wilt disease incidence and yield of cumin

Treatment	Quantity (q ha^{-1})	Per cent disease incidence			Yield (kg ha^{-1})			Net cost (Rs)	Benefit (Rs)	C:B ratio
		2004-05	2005-06	Pooled	2004-05	2005-06	Pooled			
Neem cake	30	35.72	26.39	31.05	200.75	225.25	213.00	950	5900	1:6.2
Mustard cake	25	40.86	34.45	37.65	190.50	194.50	192.50	1125	4875	1:4.3
Sesamum cake	25	35.44	28.05	31.74	230.50	216.00	223.25	825	6412	1:7.7
Cotton cake	30	42.54	36.27	39.40	200.75	215.00	207.87	1375	5643	1:4.1
Groundnut cake	30	45.37	38.25	41.81	190.75	201.75	196.25	1140	5062	1:4.4
Control		55.44	52.22	53.83	89.50	100.50	95.00	0	0	0
Sem±		1.35	1.20	0.50	0.52	0.81	9.51			
CD (P=0.05)		5.51	8.35	4.97	3.94	2.75	21.82			

Net cost=Cost of cultivation + Labour share + Rental value of instruments; Sale price of produce during 2004-06=Rs.50 kg^{-1}

(PDI 33.16) (Table 3). Sharma & Bohara (2001) observed that wilt disease severity was minimum with application of super-phosphate and goat dung. Champawat & Pathak (1988) reported that the lowest incidence of wilt disease together with maximum yield was obtained in plots treated with N, P and K at different concentrations.

Wilt disease incidence was minimum in plants grown in solarized soil (PDI 25.50) compared to non-solarized soil (PDI 48.50). Similar observations were made by Lodha (1995) and Mawar & Lodha (2002). The integrated trial indicated that solarized soil + sesamum cake @ 25 q ha^{-1} + seed treatment with carbendazim @ 0.1g g^{-1} seed had significant effect in reducing disease incidence as well as increasing yield (Table 4). Treatment with thiophanate methyl 0.1 g g^{-1} gave highest cost: benefit ratio (1:40) followed by cabendazim (0.1g g^{-1} (1:32). Among the combined treatments, the best and economical treatment was solarized soil + sesamum cake @ 25 q ha^{-1} + seed treatment with carbendazim @ 0.1 g g^{-1} seeds (1:11.4) followed by solarized soil + sesamum cake @ 25q ha^{-1} + *Azotobacter* @ 40 kg ha^{-1}. The present findings are in accordance with the findings of Jain *et al*. (1990) who reported that the soil application of neem, cotton, castor and mustard cakes (2 t ha^{-1}) in combination with seed treatment with carbendazim reduced disease incidence and increased yield over control.

The study indicated that even though the individual treatments gave the highest C : B ratio, the combined treatment of seed and soil was more effective in controlling wilt disease. Hence, the combination of solarized soil + sesamum cake @ 25 q ha^{-1} + seed treatment with carbendazim @ 0.1g g^{-1} seed can be recommended for the management of wilt disease of cumin.

Table 3. Effect of soil treatment with chemical and non-chemical manures on wilt disease of cumin

Treatment	Quantity	Per cent disease incidence			Yield (kg ha^{-1})			Net cost (Rs ha^{-1})	Benefit (Rs ha^{-1})	C:B ratio
		2004-05	2005-06	Pooled	2004-05	2005-06	Pooled			
NPK	40 kg ha^{-1}	31.20	31.27	31.23	222.50	213.50	218.00	194	3461	1:32
Vermicompost	40 q ha^{-1}	38.48	37.80	38.14	183.50	186.75	185.12	250	6225	1:18
Azotobacter (Biofertilizer)	40 kg ha^{-1}	32.92	33.40	33.16	212.75	219.50	216.12	350	4581	1:17
Control		52.99	52.22	52.60	90.75	96.25	93.50	0	0	0
Solarized soil		23.50	27.50	25.50	170.22	155.25	162.73	92	6131	1:37
Unsolarized soil		42.50	54.50	48.50	92.75	85.50	89.62	0	0	0
Sem±		0.95	0.61	1.02	2.20	1.50	8.51			
CD (P=0.05)		2.80	2.56	3.64	13.75	14.64	22.22			

Net cost=Cost of cultivation + Labour charge + Rental value of instruments; Sale price of produce during 2004-06=Rs.50 kg^{-1}

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Table 4. Combined effect of seed treatment with fungicides, soil treatment with oilcakes, manures and soil solarization on wilt of cumin

Treatment	Per cent disease incidence			Yield (kg^{-1})			Net cost (Rs ha^{-1})	Benefit (Rs ha^{-1})	C:B ratio
	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled			
Solarized soil + neem cake @ 30 q ha^{-1} + *Azotobacter* @ 40 kg ha^{-1}	28.56	26.42	27.49	325.20	320.22	322.71	1450	10,014	1:6.9
Neem cake @ 30 q ha^{-1} + solarized soil + NPK @ 40 kg ha^{-1}	25.50	25.52	25.51	316.00	330.33	323.16	1325	10,036	1:7.5
Solarized soil + neem cake @ 30 q ha^{-1} + seed treatment with carbendazim @ 0.1g g^{-1} seed	23.50	24.74	24.12	335.50	330.40	332.95	1525	10,526	1:6.9
Solarized soil + NPK @ 40 kg ha^{-1} + seed treatment with trimethyl thiuram disulphide @ 0.1 g g^{-1} seeds	26.33	28.66	27.49	315.55	312.46	314.00	1575	9578	1:6.0
Solarized soil + *Azotobacter* @ 40 kg ha^{-1} + trimethyl thiuram disulphide @ 0.1 g g^{-1}seed	32.50	33.33	32.91	310.56	309.33	309.94	1540	9375	1:6.0
Solarized soil + Sesamum cake @ 25 q ha^{-1} + *Azotobacter* @ 40 kg ha^{-1}	21.52	20.50	21.01	350.55	355.00	352.77	1650	17,638	1:10.7
Sesamum cake @ 25 q ha^{-1} + Solarized soil + NPK @ 40 kg ha^{-1}	24.74	22.50	23.62	335.56	331.00	333.28	1675	10,542	1:6.2
Solarized soil + Sesamum cake @ 25 q ha^{-1} + seed treatment with carbendazim @ 0.1 g g^{-1} seed	18.66	17.50	18.08	395.33	390.66	392.99	1725	19,649	1:11.4
Control	52.50	46.33	49.41	120.33	124.54	122.43	0	0	0
Sem±	0.11	0.56	0.84	2.95	2.25	5.21			
CD (P=0.05)	5.67	7.45	8.04	11.75	16.52	23.74			

Net cost=Cost of cultivation + Labour charge + Rental value of instruments; Sale price of produce during 2004-06=Rs.50 kg^{-1}

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Studies on nutrient management and seed rate on growth and herbage yield of fenugreek (*Trigonella corniculata* L.) cv. Kasuri in Rajasthan

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Abstract

A field experiment was conducted at Bikaner and Jalore (Rajasthan) to study the effect of fertilizer and vermicompost and four levels of seed rate on growth attributes of fenugreek (*Trigonella corniculata*) cv. Kasuri. The results showed that application of fertilizer (20 kg N + 4 kg P_2O_5 ha^{-1}) increased plant height, number of branches $plant^{-1}$, dry matter accumulation and number of root nodules, over control. Vermicompost @ 4 t ha^{-1} significantly improved growth attributes. Growth parameters such as plant height, herbage yield and dry weight of leaves, increased significantly with increasing levels of seed rate up to 7.5 kg ha^{-1}, whereas, nodules $plant^{-1}$, fresh root weight and number of branches $plant^{-1}$ decreased significantly up to 7.5 kg ha^{-1}.

Keywords: fenugreek, nutrition, *Trigonella corniculata*, seed rate, yield.

Introduction

The productivity of fenugreek (*Trigonella corniculata* L.) is low in Rajasthan, since the crop is generally grown on marginal and sub-marginal lands with limited fertilizer and organic matter addition. An adequate supply of nitrogen and phosphorus and organic manures to fenugreek will provide an efficient source to sink relationship leading to higher productivity. Furthermore, adoption of improper dose of seed rate is another impediment in realizing higher yield potential of the crop. In view of the scant information on these aspects, the present study was undertaken to standardize optimum nutrient management and seed rate on growth and herbage yield of fenugreek cv. Kasuri in Rajasthan.

Materials and methods

The first experiment was conducted at Department of Horticulture, College of Agriculture, Bikaner (Rajasthan) during *rabi* 2005-06. The soil of the experimental field was loamy sand with 85.20% sand, 6.75% silt and 8.05% clay. The experimental soil was alkaline in reaction (pH 8.4) and was low in organic carbon (0.08 %), nitrogen (62.85 kg ha^{-1}) and phosphorus (20.70 kg ha^{-1}) and had medium potassium content (170.0 kg ha^{-1}). Another experiment was conducted during *rabi*

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Table 1. Effect of nutrient management and seed rate on plant population, growth and yield of fenugreek cv. Kasuri (Pooled data of 2005-06 & 2006-07)

Nutrient and seed rate	Plant population (ha^{-1})		Plant height (cm)			Herbage yield (kg ha^{-1})		No. of branches $plant^{-1}$	No. of nodules $plant^{-1}$		Fresh root weight $plant^{-1}$	Dry root weight $plant^{-1}$
	15 DAS	150 DAS	First cutting	Second cutting	At harvest	First cutting	Second cutting		60 DAS	90 DAS		
Fertilizer (kg ha^{-1})												
No fertilizer	6244	3512	6.6	17.3	16.8	3224	489	4.6	11.8	37.8	2.39	0.81
20 N+40 P_2O_5	6396	3564	7.4	20.5	24.4	3444	7072	7.9	16.6	70.0	2.87	0.99
SEM±	56.8	46.4	0.08	0.35	0.13	40.00	86.80	0.09	0.20	1.21	0.05	0.02
CD (P=0.05)	NS	NS	0.23	0.99	0.38	113	246	0.27	0.55	3.43	0.13	0.05
Vermicompost (t ha^{-1})												
No vermicompost	6228	3492	6.7	18.1	20.1	3232	5532	5.7	12.9	46.5	2.45	0.85
4.0	6412	3588	7.3	19.7	21.0	3432	6428	6.8	15.5	61.3	2.81	0.95
SEM±	56.8	46.4	0.08	0.35	0.13	40.00	86.80	0.09	0.20	1.21	0.05	0.02
CD (P=0.05)	NS	NS	0.23	0.99	0.38	113	246	0.27	0.55	3.43	0.13	0.05
Seed rate (kg ha^{-1})												
2.5	1352	1176	2.6	7.3	9.60	1076	2384	4.1	9.2	37.2	2.00	0.57
5.0	2756	1724	3.6	8.5	10.2	1580	2736	3.2	7.6	27.7	1.40	0.49
7.5	3808	2024	3.9	10.7	10.7	1924	3388	2.7	6.2	22.9	1.06	0.40
10.0	4728	2156	3.9	11.4	10.7	2088	3452	2.5	5.4	20.0	0.80	0.34
SEM±	80.4	65.6	0.12	0.49	0.19	56.40	122.80	0.13	0.28	1.71	0.07	0.02
CD (P=0.05)	227.2	186	0.33	1.39	0.53	160	348	0.38	0.78	4.85	0.19	0.07

NS=Non significant; DAS=Days after sowing

2006-07 at Krishi Vigyan Kendra, Jalore (Rajasthan) having silty loam soil with pH 8.2, EC 0.17 dSm^{-1}, organic carbon 0.25%, phosphorus 8.6 kg P ha^{-1} and potassium 279.7 kg K ha^{-1}. The treatments comprised of two levels of fertilizers (0 and 20 kg N + 40 kg P_2O_5 ha^{-1}) and vermi compost (0 and 4.0 t ha^{-1}) and four levels of seed rate (2.5, 5.0, 7.5 and 10.0 kg ha^{-1}) and laid out in a factorial RBD with three replications. Vermicompost, nitrogen and phosphorus were applied as basal dose. Nitrogen and phosphorus were supplied through urea and single super phosphate, respectively. The crop was sown in rows spaced 25 cm apart through 'Kera' methods on 9th November 2005 and 17th November 2006 during respective years. Observations were recorded on different growth parameters of the crop.

Results and discussion

Effect of fertilizer

Application of 20 kg N + 40 kg P_2O_5 ha^{-1} significantly enhanced plant growth as manifested by increased plant height at first and second cutting and at harvest, number of nodules at 60 and 90 days after sowing (DAS), fresh and dry weight of root at pre-flowering stage, herbage yield and dry weight of leaves at first and second cutting and number of branches $plant^{-1}$ over control during both the years as well as in pooled data of two years (Table 1). Patel *et al*. (1991) have also reported hastened plant growth in fenugreek following application of nitrogen and phosphorus.

Effect of vermicompost

Application of 4 t ha^{-1} vermicompost significantly enhanced plant height at first and second cutting and at harvest, number of nodules at 60 and 90 DAS, fresh ad dry weight of root at pre-flowering stage, herbage yield and dry weight of leaves at first and second cutting and number of braches $plant^{-1}$ during both the years as well as in pooled data of two years (Table 1).

Effect of seed rate

Seed rate influenced crop growth and 10 kg ha^{-1} produced maximum plant population which was significantly higher over rest of the seed rates (Table 1). Growth parameters such as plant height at first and second cutting and at harvest, herbage yield and dry weight of leaves at first and second cutting were influenced significantly due to adoption of seed rate @ 10 kg ha^{-1} which was at par with the seed rate of 7.5 kg ha^{-1} during both the years, whereas, the pooled data over years showed significant results up to 10 kg ha^{-1}. Growth parameters of fenugreek increased significantly with decreasing seed rate. Significantly more number of branches, more number of nodules, fresh and dry weight of root and number of branches $plant^{-1}$ were recorded with the seed rate of 2.5 kg ha^{-1} than that obtained under higher seed rate. Probably, this may be due to more space available to individual plants at lower seed rate. Similar findings was also reported by Sharma (1990) in fenugreek.

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Effect of method of planting and harvesting time on growth, yield and quality of turmeric (*Curcuma longa* L.)

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Abstract

An experiment was conducted at Ludhiana (Punjab) to study the influence of method of planting (flat and ridge planting) and harvesting time (10 November-12 March) on growth, yield and of quality turmeric (*Curcuma longa*). Planting methods did not influence growth, yield and quality of turmeric significantly. Harvesting on 12th March produced maximum fresh rhizome yield of 28.94 t ha^{-1} (mean yield) of turmeric which was statistically on par with 20th February (27.61 t ha^{-1}) and 30th January (26.78 t ha^{-1}) harvesting, but was significantly better than all the earlier harvesting dates. A similar trend was observed in processed turmeric yield. The number and weight of rhizomes improved significantly with delay in harvesting. The oil and curcumin content also increased with delay in harvesting.

Keywords: *Curcuma longa*, growth, method of planting, quality, time of harvesting, turmeric, yield.

Introduction

Turmeric (*Curcuma longa* L.) offers good scope in diversification of cereal based cropping system in Punjab. The time of maturity of turmeric may vary in different agro climatic zones of the country and it is important to find out the optimum time for harvesting turmeric to fit this crop in the existing cropping system of the state. Optimum stage of harvesting plays an important role in obtaining high quality turmeric in terms of essential oil and curcumin contents. No information is available on the effect of harvesting time on yield and quality of turmeric under Punjab conditions. Hence, the present study was conducted to determine the optimum harvesting time under flat and ridge planting methods in turmeric.

Materials and methods

The investigation was carried out at Students' Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (Punjab) during 2003-04 and 2004-05. The soil of experimental field was loamy sand, normal

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with respect to pH (8.0) and EC (0.2 dSm^{-1} at 25°C), low in organic carbon (0.23%) and available nitrogen (210 kg ha^{-1}), medium in available phosphorus (17 kg ha^{-1}) and potash (207 kg ha^{-1}). The treatments consisted of two planting methods (flat and ridge) and seven dates of harvesting namely, 10th November (187 DAP), 30th November (207 DAP), 20th December (227 DAP), 10th January 247 (DAP), 30th January (267 DAP), 20th February (287 DAP) and 12th March (307 DAP). Planting of PCT-8 variety of turmeric was done on 7th May at 30 cm x 20 cm in flat planting treatment and in ridge planting treatment on ridges made at 60 cm apart with a plant to plant spacing of 10 cm to maintain uniform planting density in both the planting methods during both the years. Farmyard manure (30 t ha^{-1}) was thoroughly mixed at the time of seed bed preparation. A basal dose of phosphorus and potassium (each of 25 kg ha^{-1}) was applied at seed bed preparation; 30 kg N ha^{-1} was applied after emergence of crop. To keep the weeds under check, pendimethalin 30 EC (2.5 l ha^{-1}) was sprayed 3 days after planting and four hand weedings were also done. After hoeing (last two), earthing up in ridge planting treatment was done. Growth and yield parameters namely, plant height, green leaves $plant^{-1}$, senescence, number and weight of mother, primary and secondary rhizomes (g), were recorded at harvest. Senescence was computed as number of senescenced (dry) leaves/total number of leaves x 100. The crop was harvested by digging on different dates in both the planting methods just after the removal of shoots near the ground. The essential oil (% v/w) content was determined using Clevenger's apparatus in which 25 g of turmeric powder was distilled for 4.5 h and essential oil yield was determined. The curcumin content was determined following the method given in Thimmaiah (1999).

Results and discussion

Effect of planting method

Different planting methods did not influence the number of green leaves $plant^{-1}$, leaf senescence and the number and weight of mother, primary and secondary rhizomes, during both the years (Tables 1 & 2). Plants were taller in flat method of planting as compared to ridge method during 2003-04 and the differences were not significant during 2004-05 (Table 1).

During 2003-04, fresh turmeric rhizome yield was significantly higher in flat planting method than ridge method while the difference was not significant during 2004-05 (Table 3). Pooled analysis of the mean data indicated that the differences in fresh rhizome yield was not significant. A similar trend was observed with dry and processed yield of turmeric. The non-significant differences in fresh, dry and processed yield due to different planting methods might be attributed to the non-significant differences in growth and yield attributing characters of turmeric. The soil of the experimental field was light and low in organic carbon as well as available nitrogen due to which different planting methods might have failed to influence the yield and growth characters. Ramachandran & Muthuswami (1984) reported non-significant results in fresh rhizome yield, when turmeric was sown by different types of planting methods namely, ridge and furrow, flat bed and broad ridge method. The oil content and curcumin content in rhizome did not change significantly with different planting methods (Table 3). Kaur (2001) also reported that curcumin content did not change in flat and ridge planted turmeric at Ludhiana.

Effect of harvesting date

The effect of different harvesting dates on plant height was not significant during both the years of study (Table 1). The delay in harvesting decreased the number of green leaves $plant^{-1}$ significantly during both the years (Table 1). The reduction in number of green leaves at harvest with delay in harvesting might be due to more drying and deterioration of leaves with passage of time, especially those which come in contact with the soil. In addition to this, tearing / rotting

Table 1. Effect of planting methods and harvesting dates on growth characters of turmeric recorded at harvest

Treatment	Growth parameter					
	2003-04			2004-05		
	Height (cm)	Leaves (green) plant^{-1}	Senescence (%)	Height (cm)	Leaves (green) plant^{-1}	Senescence (%)
Planting method						
Flat	53.9	15.3	67.76 (61.77)*	54.9	14.4	77.99 (69.84)
Ridge	47.5	14.5	65.52 (59.95)	55.0	14.2	76.96 (68.91)
CD (P=0.05)	3.8	NS	NS	NS	NS	NS
Harvesting date						
10 November	47.0	17.6	21.47 (27.55)	53.0	15.5	23.98 (29.28)
30 November	47.5	16.8	27.29 (31.39)	53.4	16.5	38.84 (38.51)
20 December	48.6	16.2	48.12 (43.86)	55.2	14.6	80.99 (62.68)
10 January	51.4	14.6	69.69 (55.63)	54.0	13.7	99.45 (87.40)
30 January	52.8	14.3	100.0 (89.20)	57.9	13.6	100.0 (89.24)
20 February	51.7	13.5	100.0 (89.20)	54.3	13.3	100.0 (89.25)
12 March	52.6	11.3	100.0 (89.20)	57.5	12.8	100.0 (89.25)
CD (P=0.05)	NS	2.2	4.82	NS	1.5	2.90

*Figures in parenthesis are arc-sine transformation; Interactions: NS

of leaves also increased as harvesting was delayed. Similar results were reported by Govind & Gupta (1987), that number of leaves plant^{-1} increased only up to middle of October and thereafter number of leaves plant^{-1} became constant.

Each delay in harvesting increased the number of mother, primary and secondary rhizomes plant^{-1} except mother rhizomes during 2004-05 (Table 2). Govind & Gupta (1987) also reported that total number of rhizomes increased from 7.6 to 47.5 plant^{-1} as the harvesting of turmeric was delayed from mid of August to end of December. The effect of different harvesting dates on fresh weight of mother, primary, secondary as well as total rhizome weight plant^{-1} was significant during both the years (Table 2). With each delay in harvesting, the weight of mother, primary and secondary rhizomes increased except in case of primary (20th December) and secondary rhizome (12th March) during 2003-04. The increase in number and weight of different rhizomes with each delay in harvesting was due to the longer growth period of the plants during which they absorb more moisture and nutrients through their roots and hence resulted in increased number and weight of different rhizomes. Each delay

Table 2. Effect of planting methods and harvesting dates on number and weight of rhizomes plant^{-1}

Treatment	No. of rhizomes plant^{-1}											
	2003-04						2004-05					
	Mother		Primary		Secondary		Mother		Primary		Secondary	
	No.	Wt. (g)	No.	Wt. (g)	No.	Wt. (g)	No.	Wt. (g)	No.	Wt. (g)	No.	Wt. (g)
Planting method												
Flat	3.42	80.10	7.05	55.35	6.12	10.85	3.22	81.92	6.67	76.13	6.41	19.66
Ridge	3.45	79.85	7.38	54.17	5.11	9.36	3.14	81.98	6.73	79.84	6.34	20.35
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Harvesting date												
10 November	3.10	56.66	5.87	35.96	4.85	7.93	3.02	64.07	5.82	49.00	5.02	11.66
30 November	3.30	57.12	6.68	43.75	5.10	9.01	3.07	65.05	5.90	54.45	5.05	12.04
20 December	3.33	62.20	7.15	43.43	5.25	9.32	3.10	70.43	5.92	58.90	5.22	13.55
10 January	3.50	78.41	7.50	55.35	5.27	9.52	3.22	86.78	6.90	76.03	6.48	18.97
30 January	3.55	92.25	7.52	64.50	5.45	10.72	3.20	89.41	7.05	81.18	6.60	20.04
20 February	3.56	104.63	7.80	66.20	6.55	12.21	3.20	95.66	7.50	105.53	7.73	29.43
12 March	3.73	108.38	7.98	75.15	6.82	12.10	3.25	102.25	7.87	120.85	8.53	34.36
CD (P=0.05)	NS	15.19	NS	16.00	NS	2.07	NS	10.64	0.95	17.03	1.22	6.73

Interactions: NS

in harvesting from 10th November to 30th January increased leaf senescence significantly and complete senescence of leaf was recorded on 30th January. The more the number of green photosynthetically active leaves, more will be their contribution towards crop yield. This indicates that all the leaves of the plants became completely dry by 30th January and this might have resulted in the significant increase in turmeric yield only up to 30th January and after this date the increase in turmeric yield due to delay in harvesting was not significant.

During 2003-04, 12th March harvesting produced the highest fresh, dry and processed turmeric yield which was statistically identical to 20th February and 30th January harvesting, but was significantly better than all earlier harvesting dates (Table 3). A similar trend was observed in fresh turmeric rhizome yield during 2004-05. The dry and processed yield of 12th March was on par with January and February harvesting dates but was better than November and December harvestings.

Mean yield of data revealed that each delay in harvesting from 10th November to 12th March increased the fresh, dry and processed turmeric yield (Table 3). The increase in turmeric yield with delay in harvesting was due to increased number and weight of mother, primary, secondary as well as total rhizomes plant^{-1} (Table 2). The quantum of increase in turmeric yield was more during initial harvesting dates and this might be because when the leaves start drying, all the photosynthates are transferred to rhizomes at faster rate and result in more bulking of rhizomes plant^{-1}. However, the increase was less during the later stages (30th January, 20th February and 12th March) since the photosynthates of root only were transferred from the roots to rhizomes as the leaves had become fully dry by 30th January. In addition to this the increased uptake of moisture and nutrient by rhizome from the soil also leads to the increase in yield with each delay in harvesting date. Satheesan & Ramdasan (1988) reported that the stage of maximum rhizome growth rate of turmeric coincided

Table 3. Effect of planting methods and harvesting dates on oil and curcumin content of turmeric

Treatment	2003-04					2004-05					Mean yield		
	Fresh rhizome yield (t ha^{-1})	Dry rhizome yield (t ha^{-1})	Processed rhizome yield (t ha^{-1})	Oil content (%)	Curcumin content (%)	Fresh rhizome yield (t ha^{-1})	Dry rhizome yield (t ha^{-1})	Processed rhizome yield (t ha^{-1})	Oil content (%)	Curcumin content (%)	Fresh rhizome yield (t ha^{-1})	Dry rhizome yield (t ha^{-1})	Processed rhizome yield (t ha^{-1})
Planting method													
Flat	22.37	4.55	4.31	6.77	2.36	26.03	4.93	4.31	7.43	2.49	24.20	4.74	4.49
Ridge	19.18	4.15	3.93	6.46	2.31	26.51	5.10	3.92	7.32	2.43	22.83	4.63	4.39
CD (P=0.05)	1.70	0.34	0.31	NS	NS	NS	NS	0.31	NS	NS	NS	NS	NS
Harvesting date													
10 November	12.29	2.04	1.87	4.22	1.95	17.51	2.63	2.46	6.45	1.81	14.91	2.33	2.17
30 November	16.02	2.99	2.91	6.07	2.01	20.10	3.82	3.59	6.75	1.95	18.06	3.42	3.25
20 December	20.63	4.42	4.18	6.60	1.98	26.20	5.13	4.92	7.23	2.25	23.42	4.77	4.55
10 January	21.61	4.74	4.52	7.22	2.26	28.18	5.73	5.47	7.30	2.56	24.89	5.23	4.99
30 January	24.35	5.33	5.05	7.25	2.48	29.32	5.78	5.51	7.65	2.80	26.78	5.55	5.28
20 February	24.42	5.47	5.12	7.30	2.83	30.79	5.98	5.64	7.90	2.89	27.61	5.72	5.38
12 March	26.07	5.50	5.17	7.62	2.84	31.80	6.03	5.78	8.38	2.98	28.94	5.76	5.47
CD (P=0.05)	3.18	0.64	0.58	0.85	0.40	3.04	0.57	0.58	0.53	0.21	3.10	0.73	0.41

Interactions: NS

with reduction in starch : sugar ratio in leaves. Such marked reduction in starch : sugar ratio in leaves indicated that during rhizome bulking period, there is more translocation of photosynthates to the rhizomes. Govind & Gupta (1987) reported increased fresh rhizome yield when the harvesting was delayed from second week of August to last week of December. Subramaniam *et al*. (1978) recorded 46.3% increase in fresh rhizome yield when turmeric was harvested after 9 months as compared to the 7 months. Pachauri *et al*. (2002) also suggested that January-February is the ideal period of turmeric harvesting in the Indo-Gangetic plains of India.

The effect of different harvesting dates on oil content of turmeric was significant (Table 3). With each delay in harvesting, the oil content in turmeric improved. Maximum oil content of 7.62% and 8.38% was recorded in 12th March harvesting date during both the years and it was on par with 10th January, 30th January and 20th February harvesting dates, but was significantly better than all earlier harvesting dates during both the years of study. Govind & Gupta (1987) also reported continuous increase in oil content when harvesting of turmeric was delayed from middle of August to last week of December. With delay in harvesting curcumin content in turmeric improved. Maximum curcumin content of 2.84% and 2.98% was recorded in 12th March harvesting during 2003-04 and 2004-05, respectively and it was on par with 30th January and 20th February harvesting dates but was significantly better than all other earlier harvesting dates. Pachauri *et al*. (2002) also reported similar results and reported that the curcumin content increased with each delay in harvesting from last week of October (3.65%) to last week of February (6.01%). But Tonnesen *et al*. (1989) reported that the average content of curcumin was 1.11% which did not change significantly when the harvesting was done at weekly intervals starting from 24th October to 13th February. In conclusion, the study indicated that planting method did not influence the growth, yield and quality, whereas, delayed harvest recorded more yield and better quality in turmeric.

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Polymerase chain reaction (PCR) based indexing of black pepper (*Piper nigrum* L.) plants against *Piper yellow mottle virus*

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Abstract

A polymerase chain reaction (PCR) based method was used for indexing 845 plants representing 14 popular varieties of black pepper (*Piper nigrum*) showing no visible external symptoms (apparently healthy) for *Piper yellow mottle virus* (PYMoV), among which 694 plants were positive (82%) for PYMoV. The percentage of infected plants ranged from 59% to 100% in different varieties; 100% of the tested plants of Panniyur-6 were infected with PYMoV and Sreekara had the least number of infected plants (59%). Some of the indexed PCR positive plants exhibited visible symptoms such as mild chlorosis, yellow specks and mottling in 1-3 months after testing. The study showed that indexing by PCR successfully detected PYMoV in infected black pepper plants showing no visible symptoms. The method can be used in certification programmes to identify PYMoV-free plants for further propagation.

Keywords: black pepper, indexing, PCR, *Piper nigrum*, *Piper yellow mottle virus*.

Abbreviations: CTAB=Cetyl trimethyl ammonium bromide; DNA=Deoxyribonucleic acid; dNTP=Deoxyribonucleotide triphosphate; EDTA=Ethylene diamine tetra-acetic acid; ELISA=Enzyme linked immunosorbent assay; ORF=Open reading frame; PVP=Polyvinyl pyrrolidone; PYMoV=*Piper yellow mottle virus*.

Piper yellow mottle virus (PYMoV), a Badnavirus, is an important virus associated with black pepper (*Piper nigrum* L.) in many countries such as Brazil, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and India (Lockhart *et al*. 1997; Duarte *et al*. 2001; de Silva *et al*. 2002; Bhat *et al*. 2003; Hareesh & Bhat 2008). Mosaic, mottling, reduction in leaf size and stunting of the plant are the major symptoms of the disease. The primary spread of the disease is by infected stem cuttings used as planting material while secondary spread in the field is through different species of mealybugs (Bhat 2008).

Proper detection of causal pathogens and use of healthy planting material are the prerequisites for integrated management of viral diseases. Seasonal variation, genotype, viral load, growth stage and other factors influence the expression of symptoms in a plant. Masking of visible external symptoms especially during monsoon months was observed in black pepper indicating that symptomatology cannot be the sole criterion

in identifying infected plants. ELISA based methods also failed to provide fool-proof detection of PYMoV owing to low titre of the virus in plants (Bhadramurthy *et al*. 2005). As black pepper is clonally propagated through stem cuttings, it is important to identify virus-free plants, to be used as mother plants for further propagation. Hence in the present study, a PCR-based method was developed and used in indexing black pepper plants, the results of which are presented here.

Fourteen popular varieties of black pepper plants collected from farmers fields and Indian Institute of Spices Research (IISR), Experimental Farm, Peruvannamuzhi (Kerala) were used in the study. The popular varieties included, Sreekara, Subhakara, IISR-Malabar Excel, IISR-Girimunda, IISR-Thevam, IISR-Shakthi, Panchami, Pournami, Panniyur-1, Panniyur-2, Panniyur-3, Panniyur-4, Panniyur-5 and Panniyur-6. The first fully opened leaf from each of the plants showing no visible symptoms (apparently healthy) were collected and processed for total DNA isolation.

Total DNA was isolated slightly modifying the protocol described by de Silva *et al*. (2002). Briefly, 100 mg of leaf tissue was ground in 500 µl of CTAB buffer [100 mM Tris HCl (pH 8), 4 mM EDTA (pH 8), 1.4 M NaCl, 2% CTAB, 1% PVP, 0.5% 2-mercaptoethanol] and incubated at 65°C for 30 min. The homogenate was allowed to cool to room temperature, extracted with an equal volume of phenol : chloroform : isoamyl alcohol (25:24:1) and centrifuged at 2500 g for 10 min at room temperature. The supernatant was collected and 0.1 volume of 10% CTAB was added. This mixture was re-extracted using chloroform : isoamyl alcohol (24:1) followed by centrifugation at 2500 g for 10 min at room temperature. The supernatant was added with 0.1 volume of 3 M sodium acetate (pH 5.2) and an equal volume of isopropanol followed by incubation in ice for 30 min. The DNA was pelletized by centrifugation at 7000 g for 15 min at 4°C, washed in 70% ethanol, air dried and dissolved in 100 µl sterile distilled water.

The primer pair for PCR detection was designed based on the ORF III sequence of the virus infecting black pepper in India (GenBank accession No. DQ836227). The forward primer 5′ CTATATGAATGGCTAGTGATG 3′ and reverse primer 5′ TTCCTAGGTTTGGTATGTATG 3′represented portion of ORF-III region. The positive PCR reaction was identified by specific amplification obtained at 400 bp. The identity of the amplicon was confirmed by directly sequencing the 400 bp product in an automated sequencing facility at Genei, Bangalore. Each PCR always included a known positive (infected black pepper) and negative (healthy black pepper) controls. As virus titre was found to vary in plants, each sample was subjected to PCR using two template volumes namely, 1.0 µl and 0.5 µl in a 25 µl reaction volume. The PCR reaction contained 1 x PCR buffer, 2.5 mM $MgCl_2$, 200 µM dNTPs, 25 ng each of forward and reverse primers, 1.5 units of Taq polymerase, template DNA and sterile water to a final volume of 25 µl. The thermal cycler was programmed for initial denaturation at 94°C for 3 min, followed by 34 cycles of denaturation at 94°C for 30 s, annealing at 56°C for 1 min, synthesis at 72°C for 1 min and a final extension for 10 min at 72°C. The PCR products were analyzed on 1% agarose gel. A sample was considered positive if it gave expected amplified product using either 1.0 µl and / or 0.5 µl template volume. Total DNA isolation and PCR tests were repeated for all plants that gave negative results. The tested plants were kept under insect-proof conditions and observed for any visible symptom production.

In order to standardize the volume of template DNA required for the PCR, initially PCR was carried out using different template volumes such as 0.25 µl, 0.5 µl, 1.0 µl and 5.0 µl. Among them, 0.5 µl and 1.0 µl were found optimum. Direct sequencing of PCR

product showed 100% identity with PYMoV ORF III region sequence deposited at GenBank (DQ836227) thus confirming the specificity of the PCR product. Further, within 0.5 and 1.0 µl template volumes, 0.5 µl was found better as intensity of the band was higher (Fig. 1 a & b; Fig. 2 a & b). However, as infected field plants may contain varying concentrations of the virus, to score a plant either as positive or negative for PYMoV, each sample was subjected to PCR at two template volumes (0.5 µl and 1.0 µl) and the sample was considered positive if it gave expected amplified product either at 1.0 µl and /or 0.5 µl template volume.

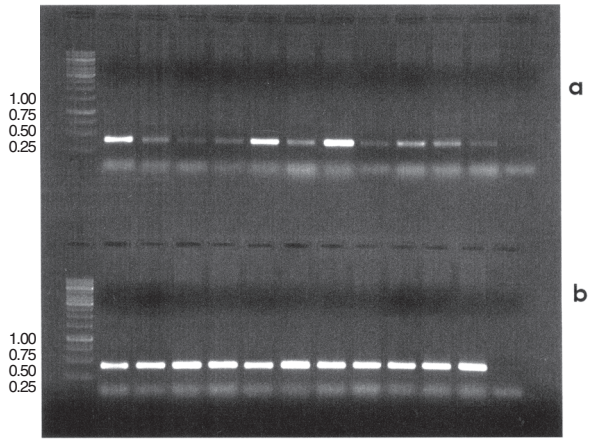

Fig. 1. Indexing black pepper plants for *Piper yellow mottle virus* (PYMoV) through PCR. Lane M: 1 Kb ladder; Lane 1: Positive control (known infected plant); Lanes 2-11: Test plants of var. Sreekara; Lane 12: Negative control (known healthy black pepper plant) (a) PCR performed with 1.0 µl template; (b) PCR performed with 0.5 µl template

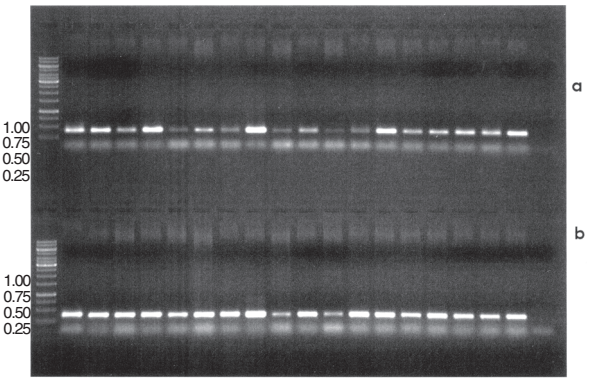

Fig. 2. Indexing black pepper plants for *Piper yellow mottle virus* (PYMoV) through PCR. Lane M: 1 Kb ladder; Lane 1: Positive control (known infected plant); Lanes 2-18: Test plants of var. Panchami; Lane 19: Negative control (known healthy black pepper plant) (a) PCR performed with 1.0 µl template; (b) PCR performed with 0.5 µl template

Among the 845 plants representing 14 varieties tested by PCR, 694 were positive for PYMoV (82%) indicating high incidence of the virus (Table 1; Figs. 1 and 2). The percentage of infected plants ranged from 59 to 100 in different varieties. Among the varieties, all the indexed plants of Panniyur-6 showed positive reaction (100%); Sreekara showed least number of infected plants (59%) (Table 1). Some of the indexed plants exhibited visible symptoms such as mild chlorosis, yellow specks and mottling in 1-3 months. The high incidence of the virus observed could be due to the use of cuttings from infected plant as source of planting material. Further, a few badnaviruses such as *Banana streak virus* and *Tobacco vein clearing virus* are known to integrate their genome into the host and such plants may remain symptomless (Harper *et al*. 1999; Lockhart *et al*. 2000). However, whether such a phenomena occur in PYMoV-black pepper system is yet to be studied.

The study showed that PCR method can be successfully used for the detection of PYMoV infection in black pepper especially in plants showing no visible symptoms. Variations in visible external symptoms from severe to complete absence of symptoms in infected black pepper plants were seen during different months of the year. This may be attributed to the influence of environmental factors on symptom expression. This kind of variation was reported for *Citrus yellow mosaic virus* infecting citrus, *Leek yellow stripe virus* infecting garlic and different viruses infecting potato (DeBokx & Piron 1977; Conci *et al*. 2002; Baranwal *et al*. 2003). When the symptoms are masked it is difficult to distinguish between healthy and infected plants. Masking of symptoms on black pepper plants infected with PYMoV makes it difficult to identify infected plants and hence sensitive

Table 1. Indexing black pepper nursery plants for the presence of PYMoV in different varieties through PCR

Variety	No. of plants tested	No. positive for PYMoV	Infected plants (%)
Sreekara	107	63	59
Subhakara	90	77	86
IISR-Thevam	58	43	74
IISR-Girimunda	43	33	77
IISR-Malabar Excel	76	59	78
Panchami	93	84	90
Pournami	47	39	83
IISR-Shakthi	64	52	81
Panniyur-1	106	104	98
Panniyur-2	23	20	87
Panniyur-3	67	58	86
Panniyur-4	11	9	82
Panniyur-5	22	15	68
Panniyur-6	38	38	100
Total	845	694	82

diagnosis is necessary to differentiate healthy and infected plants. ELISA-based method was not found to be fool proof always due to low titre of the virus in black pepper plants (Bhadramurthy *et al*. 2005). Many of the indexed PCR positive plants developed visible external symptoms with time. Similar results were also observed for *Apple stem grooving virus* in pear and apple certification program (Batlle *et al*. 2004). These results clearly indicate that a plant cannot be judged as healthy solely on the visible external symptoms but a much sensitive detection technique like PCR is useful in identifying healthy and infected black pepper plants. Thus the PCR method developed in the present study can be used in certification programmes to identify PYMoV-free plants for further propagation. The method would also be useful for screening germplasm to identify resistant sources against virus, detection in potential weed hosts and vectors and epidemiological studies.

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Effect of phosphorus and plant growth regulators on growth and yield of fenugreek (*Trigonella foenum-graecum* L.)

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Abstract

A field experiment was conducted at Mandsaur (Madhya Pradesh) to find out the effect of phosphorus and plant growth regulators on growth and yield of fenugreek (*Trigonella foenum-graecum*). The results indicated that significantly higher growth and yield (17.62 q ha^{-1}) were observed with application of 60 kg phosphorus ha^{-1}. Foliar spray of naphthalene acetic acid (NAA) 20 ppm at 25 days after sowing (DAS) and 55 DAS resulted in significantly higher growth and seed yield (17.41 q ha^{-1}). The highest benefit : cost ratio (4.20:1) was observed for the treatment, 60 kg phosphorus ha^{-1} + NAA 20 ppm.

Keywords: fenugreek, growth, growth regulator, *Trigonella foenum-graecum*, yield.

The Malwa plateau in Madhya Pradesh contributes a major share of fenugreek production (*Trigonella foenum-graecum* L.) in the state. Plant growth and seed yield increased in fenugreek when phosphorus was applied @ 60 kg ha^{-1} and sprayed with naphthalene acetic acid (NAA) @ 20 ppm (Purbey & Sen 2005). Spraying of plant growth regulators in other seed spice crops such as NAA in coriander (Pareek 1996), and gibberellic acid (GA_3) in cumin (Omer *et. al.* 1997) have been reported to improve growth and seed yield. The present investigation was carried out to study the effect of phosphorus and plant growth regulators on growth and yield of fenugreek.

The experiment was conducted at Bahadari Farm, College of Horticulture, Mandsaur, (Madhya Pradesh) (23°45′ to 24°13′ N latitude and 74°44′ to 75°18′ E longitude at an elevation of 435 m above MSL) during the *rabi* season of 2007-08. The climate of this zone is sub-tropical and average rainfall per year is 544 mm of which 90% is received during July to September. The maximum and minimum temperature during the study period was 34.24°C and 5.27°C, respectively. The mean daily maximum and minimum relative humidity varied between 65.7% to 75.9%. The soil of the experimental site was loamy in texture, with low in available nitrogen and phosphorus and high in potassium status. The experiment was laid out in a factorial randomized block design

consisting of 12 treatment combinations with 3 replications. The 12 treatment combinations consisted 3 levels of phosphorus (20, 40 and 60 kg P_2O_5 ha^{-1}) and foliar application of 4 plant growth regulators namely, NAA 20 ppm, GA_3 50 ppm, ethrel 75 ppm and distilled water spray. All the plant growth regulator treatments were sprayed at 25 and 55 days after sowing (DAS).

The seed was sown manually on 11th October 2007 in rows at a spacing of 30 cm, and the plants were thinned to 10 cm, 20 DAS and the crop was harvested on 6th March 2008. The variety RMt-1 was used for study. A uniform dose of 30 kg nitrogen ha^{-1} was applied as urea and 25 kg potassium ha^{-1} applied as muriate of potash at the time of field preparation and the different levels of phosphorus (20, 40 and 60 kg ha^{-1}) was given as di-ammonium phosphate (DAP). The plant growth regulators prepared in desired stock solution were sprayed twice (at 25 DAS and 55 DAS). Observations were recorded on growth parameters namely, plant height, number of branches, fresh and dry weight of plant and yield and yield attributes.

Effect of phosphorus

The plant growth attributes of fenugreek were highly influenced by the application of different levels of phosphorus (Table 1). Application of 60 kg phosphorus ha^{-1} resulted in significantly higher plant height (14.09, 43.28 and 77.42 cm), number of branches (4.17, 7.38 and 7.38), fresh weight of plant (88.63, 1129.07 and 3173.22 g per m^2) and dry weight of plant (13.69, 202.28 and 967.70 g per m^2) at 30 and 60 DAS and at harvest, respectively. The yield and yield attributes were also influenced significantly as a result of phosphorus application @ 60 kg ha^{-1} (Table 2). The application of phosphorus @ 60 kg ha^{-1} resulted in minimum number of days to complete 50% flowering (53.17 days). This treatment also resulted in maximum pods $plant^{-1}$ (29.96), number of seeds pod^{-1} (17.47), test weight (14.99 g), biological yield (66.22

Table 1. Effect of phosphorus and plant growth regulators on growth and yield of fenugreek

Treatment	Growth parameters											
	Plant height (cm)			No. of branches $plant^{-1}$			Fresh weight (g per m^2)			Dry weight (g per m^2)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Phosphorus (kg ha^{-1})												
20	12.34	36.83	69.24	3.49	5.71	5.71	67.27	1008.49	2859.70	8.85	150.23	763.09
40	13.59	41.92	75.27	4.07	6.77	6.77	80.80	1092.31	3047.52	11.37	183.56	826.16
60	14.09	43.28	77.42	4.17	7.38	7.38	88.63	1129.07	3173.22	13.69	202.28	967.70
SEm±	0.081	0.249	0.594	0.033	0.061	0.061	0.582	06.322	08.793	0.120	1.947	4.498
CD (P=0.05)	0.237	0.730	1.743	0.099	0.181	0.181	1.769	18.543	25.790	0.352	5.713	13.182
Growth regulator												
Water spray (Control)	13.07	38.34	71.69	3.70	6.23	6.23	75.63	1070.87	2972.01	10.43	165.15	844.03
20 ppm NAA	13.36	42.14	74.78	4.08	7.08	7.08	80.56	1097.37	3070.40	11.98	191.37	864.94
50 ppm GA^3	13.96	42.97	76.75	3.99	6.62	6.62	80.17	1069.78	3054.50	11.69	187.36	852.05
75 ppm Ethrel	13.08	39.27	72.68	3.88	6.54	6.54	79.76	1068.48	3010.34	11.12	170.88	847.37
SEm±	0.093	0.287	0.686	0.039	0.071	0.071	0.671	07.300	10.154	0.138	2.249	5.193
CD (P=0.05)	0.274	0.834	2.013	0.114	0.209	0.209	1.969	21.411	29.780	0.406	6.597	15.233

DAS=Days after sowing; NAA=Naphthalene acetic acid; GA_3=Gibberellic acid

Table 2. Effect of phosphorus and plant growth regulators on growth and yield of fenugreek

Treatment	Yield parameters							
	Days to 50% flowering	No. of pods plant^{-1}	No. of seeds pod^{-1}	Test weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Phosphorus (kg ha^{-1})								
20	53.07	28.37	15.40	12.97	14.90	45.52	60.42	24.87
40	53.48	29.53	16.51	14.02	16.65	47.73	64.88	25.71
60	53.17	29.96	14.47	14.99	17.62	48.60	66.22	26.68
SEm±	0.107	0.218	0.073	0.188	0.082	0.146	0.367	0.219
CD (P=0.05)	0.314	0.639	0.215	0.260	0.240	0.428	1.077	0.643
Growth regulator								
Water spray (Control)	56.46	24.87	15.18	13.11	15.17	42.54	57.71	26.52
20 ppm NAA	51.51	32.69	17.87	13.98	17.41	50.47	68.55	25.38
50 ppm GA^3	49.41	29.81	17.36	14.96	16.57	48.28	64.81	25.62
75 ppm Ethrel	55.58	29.77	15.42	13.90	16.40	47.88	64.28	25.49
SEm±	0.123	0.251	0.084	0.102	0.094	0.168	0.424	0.253
CD (P=0.05)	0.363	0.738	0.248	0.301	0.277	0.494	1.244	0.743

DAS=Days after sowing; NAA=Naphthalene acetic acid; GA_3=Gibberellic acid

q ha^{-1}), seed yield (17.62 q ha^{-1}), straw yield (48.60 q ha^{-1}) and harvest index (26.68%). The findings of the present investigation are in conformity with those of Pareek & Gupta (1981) and Mandal & Maiti (1992) in fenugreek, who reported that plant height, number of branches plant^{-1}, fresh weight of plant and dry weight of plant increased significantly with phosphorus fertilization.

Effect of plant growth regulators

The application of plant growth regulators significantly improved vegetative growth of fenugreek (Table 1). Among the different plant growth regulator treatments, GA^3 @ 50 ppm at 30 and 60 DAS and at harvest significantly increased plant height (13.96, 42.97 and 76.75 cm, respectively). Application of 20 ppm NAA significantly increased the number of branches at 30 and 60 DAS and at harvest (4.08, 7.08 and 7.08, respectively), fresh weight of plant (80.56, 1097.37 and 3070.40 g per m^2) at 30 and 60 DAS and at harvest, respectively and dry weight of plant (11.98, 191.37 and 864.94 g per m^2) at 30 and 60 DAS and at harvest, respectively. The yield and yield attributes were also influenced significantly as a result of application of plant growth regulators (Table 2). Application of GA^3 @ 50 ppm at 25 DAS resulted in minimum days to complete 50% flowering (49.41 days) and test weight (14.96 g). Foliar application of NAA @ 20 ppm resulted in maximum pods plant^{-1} (32.69), number of seeds pod^{-1} (17.87), biological yield (68.55 q ha^{-1}), seed yield (17.41 q ha^{-1}) and straw yield (50.47 q ha^{-1}). Significantly highest harvest index (26.52%) was recorded in water spray (control). The treatment combination 60 kg phosphorus ha^{-1} + 20 ppm NAA resulted in the highest Benefit : Cost ratio of 4.20:1 (Table 3). El-Keltwai (2000) also reported that foliar application of GA_3 encourages plant growth and gave significantly highest plant height at all stages of growth in cumin.

The study indicated that application of 60 kg P_2O_5 ha^{-1} and foliar spray of NAA 20 ppm at 25 DAS and 55 DAS gave significantly higher growth and yield of fenugreek under loamy soil condition of Mandsaur (Madhya Pradesh).

Table 3. Economics of application of phosphorus and plant growth regulators in fenugreek

Treatment	Common expenditure (Rs ha^{-1})	Extra expenditure (Rs ha^{-1})	Total cost of cultivation (Rs ha^{-1})	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	Benefit : Cost ratio
20 kg P_2O_5 + Water spray	8692	426	9118	13.33	41.11	30160	21042	3.30:1
40 kg P_2O_5 + Water spray	8692	852	9544	15.87	43.00	35016	25471	3.66:1
60 kg P_2O_5 + Water spray	8692	1278	9970	16.26	43.52	35796	25825	3.59:1
20 kg P_2O_5 + NAA 20 ppm	8692	456	9148	15.82	48.50	35751	26602	3.90:1
40 kg P_2O_5 + NAA 20 ppm	8692	882	9574	17.38	50.89	38917	29343	4.06:1
60 kg P_2O_5 + NAA 20 ppm	8692	1308	10000	19.05	52.04	42096	32095	4.20:1
20 kg P_2O_5 + GA_3 50 ppm	8692	3126	11818	15.08	46.47	34114	22296	2.88:1
40 kg P_2O_5 + GA_3 50 ppm	8692	3525	12217	16.99	48.55	37864	25647	3.09:1
60 kg P_2O_5 + GA_3 50 ppm	8692	3978	12670	17.64	49.70	39207	26236	3.09:1
20 kg P_2O_5 + Ethrel 75 ppm	8692	1126	9818	15.07	46.01	34063	24245	3.46:1
40 kg P_2O_5 + Ethrel 75 ppm	8692	1525	10217	16.62	48.48	37188	26970	3.63:1
60 kg P_2O_5 + Ethrel 75 ppm	8692	1978	10670	17.37	49.16	38640	27969	3 .62:1

NAA=Naphthalene acetic acid; GA_3=Gibberellic acid

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Performance of cassia [*Cinnamomum cassia* (Blume)] genotypes under high rainfall and high altitude Kodagu region of Karnataka

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Abstract

Fifteen cassia (*Cinnamomum aromaticum*) genotypes were evaluated for their performance for growth and yield characters under high rainfall and high altitude Kodagu region of Karnataka. Analysis of fresh and dry bark yield plant^{-1} after 7 years of planting showed significant variation among the genotypes. Among the genotypes, IC370405 exhibited superiority in terms of dry weight (1083 g plant^{-1}) and IC370408 was superior in quality.

Keywords: cassia, *Cinnamomum aromaticum*, Chinese cinnamon, yield.

Cassia (Chinese cinnamon) [*Cinnamomum cassia* (Blume)] (Family: Lauraceae) is often used as substitute for cinnamon. Cassia trees growing at 180-300 m above MSL yield better quality bark with higher volatile oil content, whereas, those growing at 90-150 m above MSL yield a relatively thick, coarse bark, somewhat deficient in flavour, containing 1.0% to 1.2% volatile oil (Pruthi 1992). Hence, the present experiment was undertaken to evaluate the performance of cassia genotypes at the high rainfall (2000-3000 mm year^{-1}) and high altitude (1000 m above MSL) Kodagu region of Karnataka.

Fifteen cassia genotypes namely, IC370401, IC370404, IC370405, IC370406, IC370408, IC370410, IC370414, IC370415, IC370418, IC370423, IC370424, IC370425, IC370427, IC370428, and IC370429 were planted as a monocrop in 2001 at the Cardamom Research Centre, Appangala (Kodagu District, Karnataka) (12°26'N latitude and 75°45'E longitude). The experiment was conducted in a randomized block design with eight replications. The vegetatively propagated genotypes (cuttings) consisted of 15 accessions as treatments (1 plant treatment^{-1}) and planted in a spacing of 2 m x 2 m. The first harvest (one time) was performed after 7 years of planting in November, and observations were recorded on various characters namely, plant height, number of branches, girth, leaf length, leaf breadth, canopy size, fresh bark yield and dry bark yield. The data was statistically analyzed by the method of Panse & Sukhatme (1995).

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Table 1. Morphological, yield and bark oil characters of cassia genotypes

Acc. No.	Plant height (cm)	No. of branches	Girth at 120 cm (cm)	Leaf length* (cm)	Leaf breadth* (cm)	Canopy (sq. m)	Bark yield (g plant^{-1})			Oil content (%)	Oleoresin content (%)	Cinnamaldehyde content (%)
							Fresh	Dry	Recovery (%)			
IC370401	444.30	22.00	19.25	20.13	5.65	6.26	1268.00	512.50	40.42	3.06	14.02	74.18
IC370404	392.50	16.33	14.50	23.53	6.03	4.73	1216.60	416.67	34.25	3.26	11.37	66.15
IC370405	410.00	16.50	17.58	22.93	5.76	3.84	2380.00	1083.30	45.50	2.37	09.97	84.20
IC370406	411.40	18.42	16.42	20.77	6.26	5.00	1285.00	450.00	35.02	1.23	11.92	67.01
IC370408	465.00	21.00	17.71	20.34	5.95	6.85	2082.50	850.00	40.82	3.71	14.14	81.58
IC370410	407.14	20.85	16.57	20.23	5.74	3.39	1613.80	623.75	38.65	2.63	12.05	69.62
IC370414	387.00	19.80	15.20	19.62	5.68	4.24	1076.30	450.00	41.81	2.65	07.52	65.07
IC370415	416.25	19.36	18.00	20.60	6.08	5.73	2040.00	608.34	29.82	3.12	10.76	78.77
IC370418	407.14	15.86	15.80	19.63	5.73	4.24	1971.60	1000.00	50.72	1.41	10.28	75.60
IC370423	395.00	20.17	19.50	21.77	5.90	4.47	1233.30	450.00	36.49	1.20	08.87	89.63
IC370424	340.71	13.43	14.86	19.63	5.82	4.31	1438.80	583.30	40.54	2.52	08.58	83.71
IC370425	347.14	16.43	14.43	20.40	5.91	3.70	1163.30	400.00	34.38	2.56	11.58	77.93
IC370427	399.30	21.83	18.00	20.47	6.02	3.98	2150.00	716.67	33.33	3.28	09.48	75.45
IC370428	375.70	16.29	17.86	20.23	5.99	5.14	2583.00	960.00	37.16	3.37	09.33	73.39
IC370429	369.38	18.63	16.88	21.27	6.19	3.75	1405.00	750.00	53.38	1.58	09.02	73.40
Mean	398.12	18.46	16.84	20.70	5.89	4.67	1645.10	626.25				
SD	57.23	03.01	02.66	01.85	0.68	1.25	499.51	163.89				
CV	28.75	32.71	31.61	17.88	23.20	53.73	60.73	52.34				
CD (P=0.01)	NS	NS	NS	NS	NS	NS	1312.20	430.53				

*3rd leaf

Dried bark of cassia (20 g) was powdered and hydro distilled for 3 h using Cleavenger trap to yield essential oil (AOAC 1975). The separated oil was collected and traces of moisture were removed using anhydrous sodium sulphate and the oil content was calculated. The constituents of the oil were analyzed using gas chromatography-flame ionization detector (GC-FID). GC-FID analysis of the oil was conducted on a Shimadzu gas chromatograph equipped with FID and RTx-5 column. Oven temperature was programmed from 70°C to 210°C at the rate of 5°C min^{-1}. FID temperature and injection port temperature were maintained at 300°C. The chief constituent of the oil was identified by comparing the retention time with that of cinnamaldehyde purchased from Sigma Chemicals. Powdered bark (10 g) was packed in a column, 60 ml acetone (AR grade) was added to it and kept overnight. The extract was drained into a weighed beaker and the coloumn containing the residue was re-extracted twice with acetone (50 ml each) at ambient conditions. The combined extract was evaporated to dryness to constant weight. From the difference in weight, the oleoresin content was calculated and expressed as percentage (AOAC 1975).

There was no significant variation for vegetative characters among the 15 genotypes under study (Table 1). Both fresh and dry bark yield characters showed more than 50% variation among the different genotypes. The highest fresh yield was recorded in IC370428 (2583 g $plant^{-1}$), which was on par with IC370405 (2380 g $plant^{-1}$) and IC370427 (2150 g $plant^{-1}$). The highest dry recovery was recorded in IC370405 (1083 g $plant^{-1}$) which was on par with IC370418 (1000 g $plant^{-1}$) and IC370428 (960 g $plant^{-1}$). Maximum per cemt dry recovery was recorded in IC370418 (50.72%).

The essential oil content varied from 1.20% (IC370423) to 3.71% (IC370408). The oleoresin content varied from 7.52% (IC370414) to 14.14% (IC370408). The highest cinnamal-dehyde content was recorded in IC370423 (89.63%) followed by IC370405 (84.20%). Maximum bark oil content of 4.9% and cinnamaldehyde content of 90.5% were recorded in cassia at Peruvannamuzhi, Kerala (IISR 2007). The superior genotypes for different characters, can be used for developing genotypes for cultivation in high rainfall and high altitude Kodagu region of Karnataka.

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Growth and yield of turmeric (*Curcuma longa* L.) intercropped in poplar (*Populus deltoides* Bartram ex Marshall) plantation at Punjab

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Abstract

The effect of planting dates and methods of planting of turmeric (*Curcuma longa*) intercropped in poplar (clone *Udai*) (*Poplulus deltoides*) plantation was studied at Ludhiana (Punjab, India). The treatments consisted of three planting dates namely, 20th March, 20th April and 20th May and two methods of planting, namely, ridge and flat method (60 cm x 10 cm) in poplar plantation. The study revealed that in first year of plantation (2004-05), a fresh rhizome yield of 9.96 t ha^{-1} was obtained in 20th April planting which was significantly more than that of 20th May planting (9.45 t ha^{-1}). During 2005-06, a fresh rhizome yield of 8.15, 11.61 and 13.95 t ha^{-1} was produced in 20th March, 20th April and 20th May planting dates, respectively. During 2006-07, the yields were lower and the differences in fresh rhizome yield due to 20th May (6.33 t ha^{-1}) and 20th April (6.43 t ha^{-1}) planting were not significant but both the planting dates were significantly better than 20th March (5.6 t ha^{-1}) planting. The ridge method of planting produced 8.0%, 11.0% and 9.8% more yield which was significantly higher than flat method of planting during 2004-05, 2005-06 and 2006-07, respectively.

Keywords: *Curcuma longa*, growth and yield, intercropping, planting pattern, poplar, *Papulus deltaides,* turmeric.

Information on the performance of different crops in compact poplar (*Populus deltoides* Bartram ex Marshall) plantation in Punjab is not available. An earlier study revealed that fresh rhizome yield of turmeric (*Curcuma longa* L.) decreased significantly as the age of poplar increases (Gill *et al*. 2004). Keeping this in view, a trial was undertaken at Ludhiana to study the effect of different planting dates and methods on the growth and yield of turmeric in compact poplar plantation.

The poplar (clone *Udai*) plantation was established during March 2004 at 5 m x 4 m spacing at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (Punjab) in an area of about 0.7 ha. The soil of experimental site was normal with respect to pH and EC, low in organic

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carbon and available nitrogen and medium in available P and K in the plough layer and the contents of these nutrients in soil decreased with increase in depth up to 90 cm of soil profile. The bulk density and particle density increased with increase in depth of plough layer.

Turmeric (var. Rajapuri) was planted in the poplar plantation during first, second and third year of plantation. The treatments consisted of three planting dates of turmeric namely, 20th March, 20th April and 20th May and two methods of planting of turmeric namely, ridge and flat method. The crop could not be planted on 20th March during 2004-05 but was only planted during 10th April since the poplar plantation was established during the last week of March. But during 2005-06 and 2006-07, turmeric was planted as per the treatments. Farmyard manure @ 30 t ha^{-1} was applied at the time of field preparation. The crop was planted both in ridge and flat methods at 60 cm x 10 cm. Two hoeings were given and earthing up was done after each hoeing to keep the crop free from weeds. Turmeric was raised as irrigated crop and the crop was harvested during the first week of February. Plant height, number of leaves plant^{-1}, number of rhizomes plant^{-1} and weight rhizome^{-1} were recorded during harvest. Analysis of variance was done following factorial experiments in RBD with three replications.

Effect of planting date

During 2004-05, the effect of planting dates on fresh rhizome yield of turmeric was significant (Table 1). The 20th April planting date produced fresh rhizome yield of 9.96 t ha^{-1} which was significantly more than that of 20th May planting date (9.45 t ha^{-1}). During 2005-06, each delay in planting date increased the fresh rhizome yield significantly and fresh rhizome yields of 8.15, 11.61 and 13.95 t ha^{-1} were produced in 20th March, 20th April and 20th May planting dates, respectively. During third year, fresh turmeric rhizome yields of 5.60, 6.43 and 6.33 t ha^{-1} were produced in 20th March, 20th April and 20th May planting dates, respectively. The differences in fresh rhizome yield due to 20th May and 20th April planting dates were not significant but both planting dates were significantly better than 20th March planting date. The fresh turmeric yield decreased during the third year in poplar plantation which might be attributed to increased poplar growth with age.

Different planting dates of turmeric in poplar plantation did not influence the growth and yield attributing characters of turmeric (plant height, number of leaves plant^{-1}, number of rhizomes plant^{-1} and weight of rhizome) recorded at harvest during 2004-05 (Table 1). But during 2005-06, plant height increased significantly with each delay in planting and maximum plant height was recorded in turmeric planted on 20th May. The differences in the number of rhizomes plant^{-1} of 20th May (7.9) and 20th April (7.8) were not significant but both treatments were significantly better than 20th March (6.5) planting date of turmeric. A similar trend was observed in the weight of rhizome though the differences were not significant. Different planting dates did not influence significantly the number of leaves plant^{-1}. During 2006-07, plant height increased with each delay in planting date and maximum plant height was recorded in 20th May planting date which was significantly better than 20th March planting date but statistically on par with 20th April planting date. The differences in weight of rhizomes per plant due to 20th May and 20th April planting dates were not significant but both treatments were significantly superior to 20th March planting date. Different planting dates of turmeric did not influence significantly the number of leaves and number of rhizomes plant^{-1}.

Effect of planting method

The effect of planting method of turmeric on fresh rhizome yield in poplar plantation was significant. The ridge method of planting turmeric produced significantly higher yield than flat method of planting. The ridge method of planting produced fresh rhizome yields of 10.08, 11.82 and 6.40 t ha^{-1} as

Table 1. Growth and yield of turmeric as influenced by planting dates and methods in poplar plantation

Treatment	Plant height (cm)	No. of leaves plant^{-1}	No. of rhizomes plant^{-1}	Weight rhizome^{-1}	Fresh yield (t ha^{-1})
			2004-05		
Planting date					
20 April	42.09	10.07	8.35	7.80	9.96
20 May	42.70	10.00	8.61	7.24	9.45
CD (P=0.05)	NS	NS	NS	NS	0.48
Planting method					
Ridge	43.50	10.25	8.22	7.83	10.08
Flat	41.29	9.82	8.74	7.21	9.33
CD (P=0.05)	2.02	NS	NS	NS	0.48
			2005-06		
Planting date					
20 March	81.6	8.5	6.5	18.14	8.15
20 April	92.3	7.8	7.8	15.68	11.61
20 May	110.8	8.5	7.9	16.68	13.95
CD (P=0.05)	6.0	NS	1.1	NS	0.69
Planting method					
Ridge	98.6	8.3	7.7	16.70	11.82
Flat	91.2	8.2	7.1	16.81	10.64
CD (P=0.05)	4.9	NS	NS	NS	0.57
			2006-07		
Planting date					
20 March	39.67	7.8	12.9	3.54	5.60
20 April	42.26	7.7	11.5	4.50	6.43
20 May	47.06	8.1	11.5	4.95	6.33
CD (P=0.05)	5.80	NS	NS	0.95	0.51
Planting method					
Ridge	46.08	8.0	13.2	4.20	6.40
Flat	41.24	7.7	10.7	4.40	5.83
CD (P=0.05)	4.80	NS	1.6	NS	0.42

compared to 9.33, 10.64 and 5.83 t ha^{-1} in flat method of planting during 2004-05, 2005-06 and 2006-07, respectively (Table 1).

The effect of planting method of turmeric on plant height in poplar was significant. The plant height of ridge planted crop was significantly higher than flat planted crop during all the three years of study. A similar trend was recorded in the number of rhizomes plant^{-1} in all the years of study though the differences were significant during 2006-07 only. The number of leaves plant^{-1} was also higher in ridge method of planting than flat method though the differences were not significant. The increased turmeric plant height, higher number of leaves plant^{-1} and more number of rhizomes plant^{-1} in this planting method resulted in higher turmeric yield in ridge method of planting than flat method. The study indicated that turmeric can be grown in poplar plantation up to 3 years though the yield decreases in the third year and crop should be planted on ridges in the third week of April in the first year whereas in the second and third years, it should be planted in the third week of May.

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