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Evaluation of nutrient management techniques to increase the seed and root yield in chicory (*Cichorium intybus* L.) for tropical zone

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Abstract
The experiment was conducted at Agricultural College and Research Institute, Madurai to maximize the seed and root yield in chicory through nutrient management techniques. The recommended dose of fertilizer was applied through inorganic and organic form (vermicompost @ 10 t ha^{-1} equivalent to the recommended dose of inorganic fertilizer) along with control. To increase the seed set and root yield, growth promoters like GA_3 (200 ppm), NAA (50 ppm), Brassinolide (0.25 ppm) and GA_3 + Brassinolide (200+ 0.25 ppm) and retardants *viz.,* cycocel (100) and paclobutrazol (50 ppm) were applied after 45 days of sowing. The result reveals that nutrients applied through inorganic is more effective for seed yield compared to organic but which is better than control. The growth promoter, brassinolide in combination with GA_3 induces early flowering (by 17.6 days earlier) along with higher LAI (7.74) and NAR (0.98 mg) resulting in maximum seed yield (5.39 g $plant^{-1}$) in inorganic forms of fertilizers. The growth retardants, paclobutrazol and cycocel, suppressed the growth and yield parameters but increased the root quality parameters

Keywords: Chicory, nutrient, growth regulators, seed and root yield, tropical zone

Introduction
Medicinal plants are natures' wonderful gift and used widely in traditional systems of medicine like Ayurveda, Siddha and Unani. Nearly 9800 species of medicinal herbs are used in human, veterinary and agricultural systems. While the usage of medicinal plants has been fully restricted to human and animal health care, no attempt has been made for exploitation in agriculture, particularly for seed treatment to maintain vigour and viability. Majority of the present day herbal industry depends on wild strata and often difficulties are experienced for sustained supply of quality seeds and planting materials, because of lack of standard package or agro technology.
Chicory (*Cichorium intybus* L.) roots are widely used for blending with coffee and grown for beverage industry [1]. Besides, it has manifold medicinal uses. Chicory leaves are fairly good source of crude protein and rich in nutrients [2], antioxidant properties [3] and the roots contain high proportion of the storage polysaccharide inulin which is used as a low-calorie sweetening agent [4]. The research work on the cultivation of this crop as a medicinal plant is relatively meagre and restricted to temperate zone [5]. Pertinent work on standardization of seed production techniques in tropical conditions has not been initiated so far. Against this back drop, studies were conducted in chicory (*Cichorium intybus* L.) to standardize the seed production techniques in tropical zones.

Materials and Methods
Chicory seeds collected from Kothari Phytochemicals International Company, Madurai were cleaned, dried (approx. 10 $\pm$ 0.5%) and used for the study. Field experiment was conducted at Agricultural College and Research Institute, Madurai. The fertilizer in the forms of organic and inorganic and growth regulators and retardants were applied to increase the root and seed yield. The inorganic form was applied as NPK @ 120:55:80 kg ha^{-1}. Half of nitrogen and whole of phosphorus and potash were applied as basally and the remaining nitrogen was top dressed at 30 days after sowing (DAS). The organic form of fertilizer was applied as vermicompost @10 t ha^{-1} as basal which is equivalent to the recommended doses of inorganic fertilizer (120:55:80 NPK kg ha^{-1}- calculated based on the NPK composition of

vermicompost). The growth regulators *viz.,* gibberellic acid (GA_3-200 ppm), naphthalene acetic acid (NAA-50 ppm), brassinolide (0.25 ppm), combination of brassinolide and gibberellic acid (200+ 0.25 ppm) and retardants namely cycocel (100 ppm) and paclobutrazol (50 ppm) were sprayed at 45 days after sowing. The other recommended packages of practices were followed through out the crop period. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications. Ten plants were selected at random from each replication to record the plant biometric, root and seed yield parameters at 75 and 100 days after sowing (vegetative and flowering stage, respectively).

Biometric observations *viz.,* plant height was measured from cotyledonary node to the base of last open leaf and the mean arrived, expressed in cm. Leaf area index, crop growth rate and net assimilation rate were determined [6]. Flower initiation was recorded based on the number of days required for first flowering from the date of sowing in five rows and the average calculated. Root girth (cm), root fresh and dry weight were measured and expressed in gram. For seed yield, the seeds from five plants were separated and dried at 35 ^{0}C for two days and weight was expressed in gram. Root yield was calculated by harvesting five plants at random and cut the roots, washed and dried at 80 ^{0}C for 16 h in an oven, weighed and expressed in gram. The results of the experiment was subjected to an Analysis of Variance and treatment differences tested (t test) for significance (P=0.05) [7].

Results

In the present study, application of NPK through inorganics proved better result in terms of plant height (69.7 cm) over vermicompost (63.8 cm) and control (56.7 cm). Among the foliar sprays, brassinolide in combination with GA_3 produced taller plants (86.5 cm). The growth retardants namely paclobutrazol and cycocel reduced the plant height (45.0 and 44.9 cm). In both the forms of nutrient application, taller plant was produced in brassinolide and GA_3 combination (99.0 and 87.0 cm) followed by GA_3 (89.0 and 82.7 cm) compared to control (60.3 and 56.8 cm) (Table 1). Inorganic form of NPK, initiated earlier flowering by 2.2 days over vermicompost and 6.1 days over control. In the same treatment, brassinolide combined with GA_3 recorded earlier flowering by 17.6 days over control. This was closely followed by GA_3 (by 15.3 days) and NAA (by 6.3 days). Cycocel delayed the flowering by 16.5 days over control (Table 1). Inorganic form of nutrients recorded higher leaf area index over vermicompost. In inorganic forms, the brassinolide combined with GA_3 gave more leaf area index and was closely followed by GA_3 with an increase of 153.7 and 110.8 per cent respectively, compared to control. In paclobutrazol and cycocel the leaf area index had a decline by 109.7 and 141.1 per cent over brassinolide combined with GA_3 (Fig.1). Similar trend was followed in vermicompost, but the magnitude of increase was less compared to inorganic. The maximum value for crop growth rate (CGR) was recorded in NPK applied through inorganics over vermicompost. Among the foliar sprays, the brassinolide and GA_3 combination had a higher crop growth rate (73.9g) compared to control (20.15 g). This was closely followed by GA_3 and NAA (61.6 and 48.4 g). The paclobutrazol and cycocel had lesser value (29.6 and 20.3 g). Similar trend but at a lower rate was observed in vermicompost (Fig. 1). The nutrients applied through inorganic form sprayed with brassinolide combined with GA_3 recorded higher value for net assimilation rate (NAR) (0.98 mg) followed by GA_3 (0.95 mg) and brassinolide (0.95 mg) over control (0.69 mg). The paclobutrazol and cycocel recorded only 0.82 and 0.65 mg. In both the forms of nutrient application, the maximum NAR was recorded in brassinolide combined with GA_3 (0.98 and 0.87 mg) over control (0.69 and 0.47 mg) (Fig. 1).

Application of NPK through inorganic form proved better for root fresh weight (7.4 g) than vermicompost (6.9 g). Cycocel spray increased the root fresh weight by 2.9 g over control. The paclobutrazol and brassinolide with GA_3 combination had an equal effect recording an increase of 2.3 and 2.1g, respectively over control (Table 2). In inorganic form of application, the retardants cycocel and paclobutrazol recorded an increase in root dry weight by 1.1 and 0.9 g over control. The same treatments in vermicompost had an increase of 1.0 and 0.7 g over control (Table 3). Application of fertilizer through inorganic proved for better root girth than vermicompost (by 0.37 cm). The growth retardant namely cycocel enhanced maximum girth over control (by 2.61 cm). This was closely followed by brassinolide and GA_3 combination and paclobutrazol (by 1.90 and 1.80 cm) (Table 4). The inorganic form of NPK application enhanced root yield by 10.7 per cent compared to vermicompost and 29 per cent over control. The root yield was high in growth retardants by 45.4 per cent in cycocel and 36.3 per cent in paclobutrazol compared to control. Combined application of brassinolide and GA_3 behaved similar to paclobutrazol (Table 4). Maximum seed yield was obtained in inorganic form with foliar spray of brassinolide combined with GA_3 accounting an increase of 94.6 per cent, followed by GA_3 (78.3 %) and NAA (by 57 %) over control. A reduction of yield was recorded in cycocel applied plants (8 %) compared to control (Fig. 1). Vermicompost, which was less effective than inorganic form was effective than control in all treatments

Table 1: Effect of growth regulators and nutrients on plant height and flower initiation in chicory (*cichorium intybus* L.) cv. Kalpa

Treatments/ Fertilizers	Plant height (cm)										Flower initiation (Days)			
	Control			Fertilizer			Vermicompost				Control	Fertilizer	Vermicompost	Grand mean
	75 DAS	110 DAS	Mean	75 DAS	110 DAS	Mean	75 DAS	110 DAS	Mean	Grand Mean				
Control	33.6	62.7	48.2	39.9	80.7	60.3	38.1	75.5	56.8	55.1	96.2	92.1	94.3	94.2
GA_3 (200 ppm)	49.7	86.3	68.0	62.9	115.1	89.0	62.6	102.8	82.7	79.9	87.9	76.8	83.7	82.8
NAA (50 ppm)	44.0	79.5	61.8	56.9	105.4	81.2	52.9	92.8	72.9	71.9	89.9	85.8	86.2	87.3
Paclobutrazal (50 ppm)	27.7	50.1	38.9	36.5	63.5	50.0	35.6	56.8	46.2	45.0	93.7	89.9	91.5	91.7
Cycocel (100 ppm)	23.2	75.0	49.1	34.5	55.0	44.8	32.9	48.7	40.8	44.9	115.1	108.6	106.5	110.1
Brassinolide (0.25 ppm)	40.2	74.9	57.6	45.1	83.1	64.1	45.6	75.4	60.5	60.7	90.7	89.6	89.6	90.0
Brassinolide + GA_3 (0.25 ppm+ 200)	55.5	91.5	73.5	79.4	118.5	99.0	64.2	109.8	87.0	86.5	86.7	74.5	81.2	80.8
Mean			56.7			69.7			63.8		94.3	88.2	90.4	
	F	T	G	FT	FG	TG	FTG				F	T	FT	
SEd	1.35	1.79	1.17	3.10	2.34	3.58	0.75				0.73	1.11	1.93	
CD (P=0.05)	2.65	3.51	2.29	6.08	4.59	7.02	1.49				1.47	2.25	3.98	

75 Days after Sowing (DAS) – Vegetative Stage

110 Days after Sowing (DAS) – Flowering Stage

Table 2: Effect of growth regulators and nutrients on root fresh weight in chicory (cichorium intybus L.) cv. Kalpa

Treatments/ Fertilizers	Root fresh weight (g $plant^{-1}$)									
	Control			Fertilizer			Vermicompost			
	75 DAS	110 DAS	Mean	75 DAS	110 DAS	Mean	75 DAS	110 DAS	Mean	Grand Mean
Control	4.3	5.4	4.9	5.7	5.8	5.8	4.4	5.6	5.0	5.2
GA_3 (200 ppm)	5.4	6.2	5.8	6.3	7.0	6.6	6.0	6.8	6.4	6.3
NAA (50 ppm)	6.2	7.0	6.6	6.8	8.1	7.5	6.4	7.7	7.1	7.1
Paclobutrazal (50 ppm)	6.4	7.5	7.0	7.8	8.4	8.1	6.7	8.0	7.4	7.5
Cycocel (100 ppm)	7.2	8.0	7.6	8.1	9.1	8.6	7.7	8.3	8.0	8.1
Brassinolide (0.25 ppm)	6.3	7.2	6.8	6.6	7.5	7.1	6.4	7.3	6.9	6.9
Brassinolide + GA_3 (0.25 ppm+ 200)	6.6	7.2	6.9	7.4	8.2	7.8	6.9	7.6	7.3	7.3
Mean			6.5			7.4			6.9	
	F	T	G	FT	FG	TG	FTG			
SEd	0.05	0.08	0.06	0.13	0.10	0.16	0.27			
CD (P=0.05)	0.10	0.15	0.11	0.27	NS	0.31	NS			

Table 3: Effect of growth regulators and nutrients on root dry weight in chicory (*cichorium intybus* L.) cv. Kalpa

Treatments/ Fertilizers	Root dry weight (g $plant^{-1}$)									
	Control			Fertilizer			Vermicompost			
	75 DAS	110 DAS	Mean	75 DAS	110 DAS	Mean	75 DAS	110 DAS	Mean	Grand mean
Control	1.4	1.9	1.7	1.9	2.3	2.1	1.7	2.1	1.9	1.9
GA_3 (200 ppm)	1.6	1.9	1.8	2.1	2.7	2.4	1.9	2.5	2.2	2.1
NAA (50 ppm)	1.7	2.1	1.9	2.4	2.9	2.7	2.0	2.7	2.4	2.3
Paclobutrazal (50 ppm)	1.8	2.2	2.0	2.7	3.3	3.0	2.1	3.0	2.6	2.5
Cycocel (100 ppm)	2.0	2.9	2.5	2.9	3.5	3.2	2.5	3.3	2.9	2.9
Brassinolide (0.25 ppm)	1.7	2.0	1.9	2.2	3.1	2.7	2.1	2.5	2.3	2.3
Brassinolide + GA_3 (0.25 ppm+ 200)	1.8	2.2	2.0	2.6	3.2	2.9	2.2	2.8	2.5	2.5
Mean			2.0			2.7			2.4	
	F	T	G	FT	FG	TG	FTG			
SEd	0.04	0.06	0.05	0.11	0.08	0.13	0.22			
CD (P=0.05)	0.08	0.12	0.09	0.21	NS	NS	NS			

Table 4: Effect of growth regulators and nutrients on root girth and root yield in chicory (*cichorium intybus* L.) cv. Kalpa

Treatments/ Fertilizers	Root girth (cm)										Root yield (g $plant^{-1}$)			
	Control			Fertilizer			vermicompost							
	75 DAS	110 DAS	Mean	75 DAS	110 DAS	Mean	75 DAS	110 DAS	Mean	Grand Mean	Control	Fertilizer	vermicompost	Grand Mean
Control	3.7	4.8	4.2	4.3	5.6	5.0	4.0	5.1	4.6	4.6	2.0	2.4	2.3	2.2
GA_3 (200 ppm)	4.5	5.6	5.0	4.9	6.3	5.6	4.6	6.0	5.3	5.3	2.1	2.7	2.5	2.4
NAA (50 ppm	5.7	6.3	6.0	5.7	7.1	6.4	5.1	6.8	6.0	6.1	2.2	3.0	2.8	2.7
Paclobutrazal (50 ppm)	5.3	6.5	5.9	6.4	7.2	6.8	6.0	6.9	6.5	6.4	2.6	3.4	3.1	3.0
Cycocel (100 ppm)	6.2	7.2	6.7	7.2	8.3	7.8	6.9	7.5	7.2	7.2	2.8	3.6	3.4	3.2
Brassinolide (0.25 ppm)	5.4	6.3	5.8	6.0	6.6	6.3	5.7	6.4	6.1	6.1	2.4	3.2	2.5	2.7
Brassinolide + GA_3 (0.25 ppm+ 200)	5.9	6.6	6.2	6.3	7.2	6.8	6.1	6.9	6.5	6.5	2.5	3.3	2.9	2.9
Mean			5.7			6.4			6.1		2.4	3.1	2.8	
	F	T	G	FT	FG	TG	FTG				F	T	FT	
SEd	0.05	0.08	0.06	0.15	0.11	0.17	0.30				0.06	0.08	0.11	
CD (P=0.05)	1.10	0.16	0.12	0.29	NS	0.33	NS				0.13	0.16	0.23	

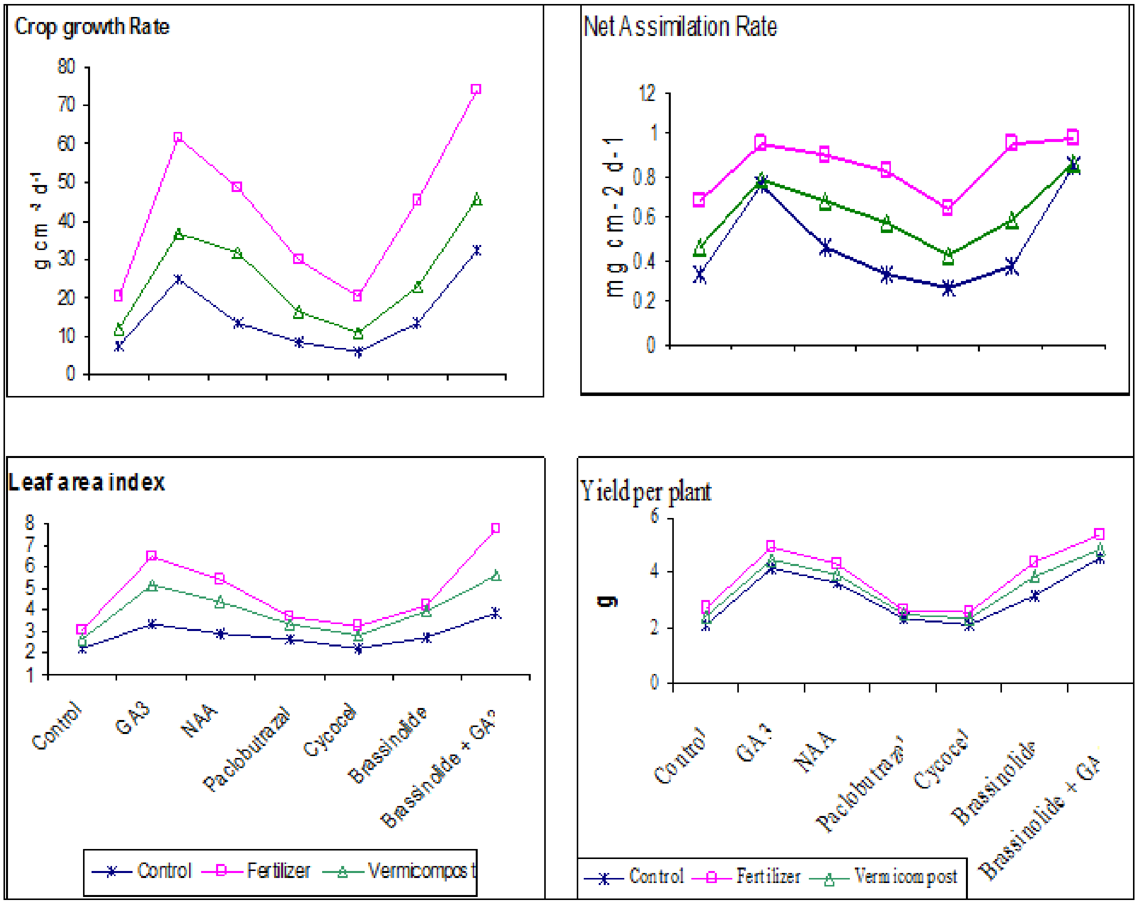

Fig 1: Influence of growth regulators and nutrients on biometric and yield parameters in chicory (*cichorium intybus* L.) cv. Kalpa

Discussion

Studies on standardization of seed production techniques using growth promoters and retardants with a constant fertilizer dose (120:55:80 kg NPK/ha) supplied either inorganic fertilizer or vermicompost revealed the advantageous effect of inorganics over vermicompost for seed and root yield. This may probably be due to easy application of available form of inorganic fertilizers at all growth stages. However, in the present day of alarming situation, use of inorganic fertilizer necessitates soil management practices to maintain fertility and stabilize crop productivity through organic farming. This would also influence the availability of micronutrients to the plants [8].

Chicory flowering is linked with photo induction by long day cycles [9]. If the conditions are reversed using growth regulators to avoid cold and long day treatments that are not prevalent in Tamil Nadu, seed production in this crop will gain momentum in this part of the country. In the present study, GA_3 either alone or in combination with brassinolide promoted the physiological or yield parameters. GA_3 has been reported to influence translocation of photosynthates [10], flowering [11], fruit set and weight of seeds [12]. Brassinolides are a group of naturally occurring plant steroidal compounds with wide biological activity capable of increasing crop yields through changing plant metabolisms and protecting them from environmental stress. They can induce cellular response like stem elongation, pollen tube growth, xylem differentiation, chlorophyll stability, fresh and dry weight and early flowering [13] and also higher nitrate reductase and carbonic anhydrase activity [14]. Brassinolide interacts with other plant hormones particularly GA_3 to have an additive effect [15]. In the present study also, maximum positive effect on all the physiological and yield attributes was observed in brassinolide and GA_3 combination. It is evident that brassinolide in combination with GA_3 appeared to be non-toxic and eco-friendly and the positive effects could be observed for most of yield parameters, particularly at lower concentrations.

Since the commercial product of chicory is root, the treatment for induction of early flowering and seed yield also should bring higher root yield. With this objective, growth retardants paclobutrazol and cycocel were attempted with a view to modifying canopy structure by reducing stem length [16]. Under the influence of these retardants, most of the growth parameters were adversely affected except root characteristics which were higher in paclobutrazol and cycocel treatments. These results confirmed the findings of Dalziel and Lawrence [17] according to whom, paclobutrazol and cycocel induced suppression of GA_3 biosynthesis, thereby affecting bud initiation and branching in plants. Observations in the present study revealed that paclobutrazol and cycocel sprayed plants were closely packed, which may be due to dominance of main shoot. Hence, it may be concluded that in chicory, higher seed yield could be obtained when the recommended fertilizer is applied through inorganic form. Vermicompost was better than control but the effect was less. Growth promoters, brassinolide in combination with GA_3 enhanced the physiological and yield attributes, can be recommended for higher seed yield. Paclobutrazol and cycocel reduced the seed yield and not the root yield, will be effective for an enhancement of root yield in chicory.

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