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STUDIES ON IMPROVEMENT OF SEEDLING VIGOUR IN TNAU PAPAYA CO.8 (*Carica papaya* L.)

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ABSTRACT
A study comprising four different experiments in order to find out the best seed treatment, potting media, chemical and bio inoculants experiments to improve the seedling vigour in TNAU Papaya CO 8 was conducted at University Orchard, Horticultural College and Research Institute, TNAU, Coimbatore during 2015 – 2016. Experiment was conducted to study the effect of seven different seed treatments *viz*., Halo polymer @ 3ml kg^{-1} for 2 minutes (S_2), KNO_3 @ 1.0 % for 12 hours (S_3), KH_2PO_4 @ 1.0 % for 12 hours (S_4), PPFM @ 2.0 % for 12 hours (S_5), KCl @ 2.0 % for 12 hours (S_6) and GA_3 @ 200 ppm (S_7) along with control (S_1). Among the treatments, KNO_3 @ 1.0 % for 12 hours (S_3) followed by PPFM @ 2.0 % for 12 hours (S_5) showed positive significant influence on seed germination, seedling growth parameters *viz*., seedling height, girth, shoot and root biomass. Experiment II was conducted to study the effect of potting media on seedling growth and vigor. Different combinations of potting media *viz*., control (M_1), Cocopeat + Vermicompost + *Azospirillum* + Phosphobacteria (M_2), Cocopeat + Vermicompost + *Pseudomonas fluorescens* (M_3), Cocopeat + *Azospirillum* + Phosphobacteria (M_4), Cocopeat + *Azospirillum* + Phosphobacteria + *Pseudomonas fluorescens* (M_5) and Cocopeat + Vermicompost + *Azospirillum* + Phosphobacteria + *Pseudomonasfluorescens* (M_6) were evaluated and compared. The best results were obtained by Cocopeat + Vermicompost + *Azospirillum* + Phosphobacteria + *Pseudomonas fluorescens* (M_6) followed by Cocopeat + Vermicompost + *Pseudomonas fluorescens* (M_3) which showed highest seed germination percentage, seedling height, seedling girth, leaf nutrient contents, chlorophyll content and leaf soluble protein content.Experiment III was conducted to study the effect of application of chemicals and bio-inoculants on one month old seedlings to improve the seedling growth and vigour. It included seven treatments *viz*., control (CB_1), DAP @ 0.25 % (CB_2), DAP @ 0.5 % (CB_3), KH_2PO_4 @ 0.25 % (CB_4), KH_2PO_4 @ 0.5 % (CB_5), PPFM @ 1.0 % (CB_6) and PPFM @ 2.0 % (CB_7). Seedling drenched with KH_2PO_4 @ 0.5 % (CB_5) followed by PPFM @ 2.0 % (CB_7) showed the highest seedling growth parameters. Eventually, to find out the combination effect, the best two treatments from the previous experiments were evaluated in experiment IV. Different combinations of media used were T_1 (S_3+M_6+CB_5) T_2 (S_3+M_6+CB_7) T3 (S_3+M_3+CB_5), T4 (S3+M_3+CB_7), T_5 (S_5+M_6+CB_5), T_6 (S_5+M_6+CB_7), T_7 (S_3+M_3+CB_5) and T_8 (S_5+M_3+CB_7). All the treatments were on par with respect to seed germination percentage and seedling growth parameters while leaf nutrient content, chlorophyll and leaf soluble protein content differed significantly among treatments but the treatment T_3 (S_3+M_3+CB_5), wherein the seeds treated with KNO_3 @ 1.0% for 12 hours (S_3), sown in potting media comprising of Cocopeat + Vermicompost + *Pseudomonas fluorescens* (M_3) + drenching the seedlings with KH_2PO_4 1.0% at one month after sowing (T_3) was adjudged as the best for improvement of seed germination, seedling growth and vigour.

KEY WORDS: Chemicals, potting mixtures, bio-inoculants, papaya, seedling vigour

INTRODUCTION

Papaya (*Carica papaya* L.) has been known as a "*Wonder fruit of the tropics"* belongs to the family Caricaceae and is the only member of the genus *Carica* (Badillo, 2000). Of late, papaya production is seriously hampered by the major viral disease Papaya Ring Spot Virus (PRSV) and root rot diseases caused by *Pythium aphanidermatum*, *Rhizoctania solani* and *Phytophthora spp.* One way of imparting tolerance to these maladies, is improving the plant vigour. Papaya is mainly propagated through seeds. The quality of seedlings obtained from a nursery influences re-establishment in the field and the eventual productivity of an orchard. Plant vigour depends on the seedling vigour. Hence attention has to be given right from nursery stage itself in order to improve the seedling vigour. Seedling vigour is affected by many factors like seed quality and seed treatments, type of substrate used, environmental factors etc. Some of the problems faced by papaya growers are slow, erratic and incomplete germination of papaya, high initial seedling mortality and incidence of soil borne diseases. In heavy soil without enough drainage, the development of root system is suppressed and plants are more susceptible to soil borne diseases. Thus increasing germination percentage and producing healthier seedling is a major challenge to farmers. Use of suitable growing media or substrate is essential for production of high quality seedlings. A good growing media would provide proper anchorage or support to the plant, serves as a nutrient and water reservoir and permits gaseous exchange between roots and atmosphere (Anjanawe *et al.* 2013). The significant role of chemical treatment through KNO_3, and gibberellic acid in relation to

breaking dormancy, seed germination, growth and development of plant has been observed (Kadam, 1992). Germination of papaya seeds can be improved by various pre-sowing seed treatments (Mederos and Hernandez, 1988). The effect of media on seed germination and seedling growth has been studied by various workers in papaya (Handa *et al.* 2005; Baiyeri and Mbah, 2006; Karthikeyan *et al.,* 2009; Anjanawe *et al.,* 2013; Bhardwaj,2014; Kumawat *et al.*, 2014 and Ramteke *et al.*, 2015) under different agro-climatic conditions. The effect of nursery application of biofertilizers viz., *Azospirillum*, VAM and Phosphobacteria on improvement of seedling growth and vigour was reported by Padma (1988).Hence, the current study is to find out the effect of seed treatments, potting media, chemicals and bio-inoculants in improving seedling growth and vigour of TNAU Papaya CO.8 with following objectives. To study the effect of seed treatments, potting media, chemicals and bio-inoculants *per se*on germination, seedling growth and vigour of papaya. To study the combined effect of seed treatments, potting mixtures, chemicals and bio-inoculants on germination, seedling growth and vigour of papaya.

MATERIALS & METHODS

The four experiments were conducted at the nursery, University Orchard, Department of Fruit Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 2015-2016. The design adopted for these four experiments was Completely Randomized Block Design (CRD) with three replications in polythene bags. For each replication 25 polythene bags were raised for this study. Six seeds were sown at 0.5-1.0 cm depth in black polythene bags of 15 x 10 cm size and polybag thickness in 150 gauge. Experiment comprised of seven different seed treatments *viz*., Control (S_1), Halo polymer @ 3ml kg^{-1} for 2 minutes (S_2), Potassium nitrate (KNO_3) 1.0 % for 12 hours (S_3), Potassium dihydrogen orthophosphate (KH_2PO_4) 1.0 % for 12 hours (S_4), Pink Pigmented Facultative Methylotrophs (PPFM) 2.0 % for 12 hours (S_5), Potassium chloride (KCl) 2.0 % for 12 hours (S_6) and Gibberellic acid (GA_3) 200 ppm (S_7). The seeds after imposing treatments were sown in polythene bag containing potting media comprising of FYM: red soil: sand @ 1:2:1 ratio.

Experiment II comprised of six different potting media were used based on the earlier studies conducted in papaya and other crops. *viz*., control (M_1), cocopeat + vermicompost + *azospirillum* + phosphobacteria (M_2), cocopeat + vermicompost + *pseudomonasfluorescens* (M_3), cocopeat + *azospirillum* + phosphobacteria (M_4), cocopeat + *azospirillum* + phosphobacteria + *pseudomonas fluorescens* (M_5) and cocopeat + vermicompost + *azospirillum* + phosphobacteria + *pseudomonasfluorescens* (M_6) The seeds of Co.8 papaya were sown in the pre-filled polybags.

Experiment III Chemicals and Bio-inoculants (CB) were drenched in the polythene bag containing potting media comprising of FYM: red soil: sand @ 1:2:1 ratio at one month after sowing of seedlings. Comprised of seven treatments *viz*., control (CB_1), Di ammonium Phosphate (DAP) @ 0.25 % (CB_2), Di ammonium Phosphate (DAP) @ 0.5 % (CB_3), Potassium dihydrogen orthophosphate (KH_2PO_4) @ 0.25 % (CB_4), Potassium dihydrogen orthophosphate (KH_2PO_4) @ 0.5 % (CB_5), Pink Pigmented Facultative Methylotrophs (PPFM) @ 1.0 % (CB_6) and Pink Pigmented Facultative Methylotrophs (PPFM) @ 2.0 % (CB_7).

Experiment IV to study the combined effect of seed treatment, potting media, chemicals and bio inoculants on seedling growth and vigour of TNAU Papaya CO 8, the best two treatments from experiment I, II and III were selected and combined and totally eight treatments were comprised *viz*., T_1 (S_3+M_6+CB_5) T_2 (S_3+M_6+CB_7) T3 (S_3+M_3+CB_5), T4 (S_3+M_3+CB_7), T_5 (S_5+M_6+CB_5), T_6 (S_5+M_6+CB_7), T_7 (S_3+M_3+CB_5) and T_8 (S_5+M_3+CB_7).{S_3- KNO_3 @ 1.0 %; S_5- PPFM @ 2.0 %; M_3- Cocopeat + Vermicompost +*Pseudomonas fluorescens* ; M_6- Cocopeat + Vermicompost + *Azospirillum* + Phosphobacteria + *Pseudomonas fluorescens*; CB_5- KH_2PO_4 @ 0.5 % and CB_7- PPFM @ 2.0 %.}

The observations on germination parameters were recorded at the time of germination and for seedling growth parameters, the observations were taken at seven days interval from one month after germination at 37, 44 and 51 days after sowing. The germination percentage was calculated by taking observation starting from the first germination to no further germination as per the formula, by dividing number of seeds sown with the number of germinated seedlings and multiplied by 100.

Rate of emergence

Three replicates of four fifty seeds from each treatment were used to test the speed of germination of seeds from different treatments. The seeds showing radicle protrusion more than 3.0 mm was counted daily from tenth day after sowing until thirty days. From the number of seeds germinated on each day, the speed of germination was calculated using the following formula and the result was expressed in whole number (Maguire, 1962).

$$\textbf{Rate of emergence} = (X_1 \lfloor Y_1) + (X_2 - X_1/Y_2) + \ldots X_n - (X_n - 1)/Y_n$$

X_1- number of seeds germinated at first count
X_2- number of seeds germinated at second count
X_n- number of seeds germinated on n^{th} day
Y_1- number of days from sowing to first count
Y_2- number of days from sowing to second count
Y_n- number of days from sowing to n^{th} count

Vigour index

Vigour index was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) and expressed in whole number.

Vigour index = Germination (%) x Total seedling length (cm)

RESULTS & DISCUSSION

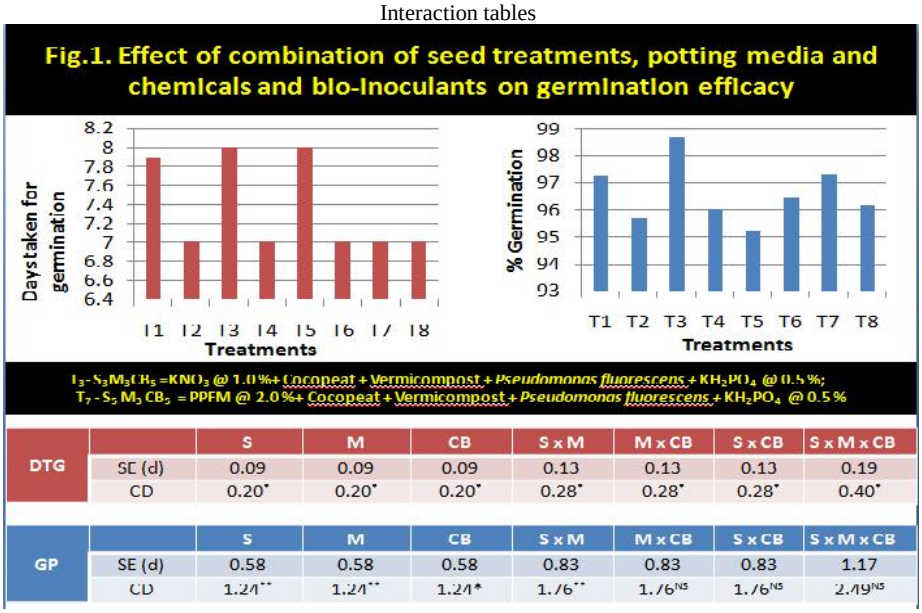
A good growing medium for the nursery is of vital importance as it promotes water absorption, nutrient availability and oxygen supply to the germinating seeds and seedlings. Growing media not only acts as a growing place but also as a source of nutrient for plant growth. Media composition used influences the quality of seedlings (Wilson *et al*., 2001). In this experiment, the best two of each from the Experiment I, II and III were combined in order to study the interaction effect of seed treatments, media and chemical/ bio-inoculant application in the nursery. In the present study, the combined effects of seed treatments, potting media and application of chemicals and bio inoculants surpassed to those of individual effect. Similar conclusions were drawn by Angeline and Ouma (2008). However, the results analysed using three-way ANOVA indicated that the treatment combinations were found to be statistically non-significant for many of the growth parameters *viz*., days taken for germination, germination percentage, rate of emergence, leaf area, vigour index, shoot and root biomass and days taken to attain 15 cm height of the seedlings. On the other hand, significant differences were recorded only for the leaf nutrient and biochemical components such as leaf N, P, K, leaf chlorophyll content, leaf soluble protein contents in the seedlings. Among the statistically significant characters, the treatment comprising of seed treatment with KNO_3 @ 1.0 % (S_3) + sown in Cocopeat + Vermicompost + *Pseudomonas fluorescens* (M_3) + drenching the seedlings with KH_2PO_4 1.0% (CB_5) at one month after sowing (T_3) was found to besuperior over other treatments. Further, the results indicated the more pronounced effect of combination of all the three components viz., seed treatment, potting media and chemical application over individual effect.

The interaction effect of three factors indicated that the days taken for germination was reduced by 17.17% and days taken to attain 15 cm seedling height by 2.13% in T_3 over individual effect. The rate of emergence increased by 10.28%. This revealed the significance of combined effect of seed treatments along with potting media compared to seed treatment alone. The interaction effect of individual components indicated that seed treatment in combination with potting media (S x M) was found to be significant for most of the parameters as compared to seed treatments (S) x chemicals and bio inoculants (CB) and potting media (M) x chemicals and bio inoculants (CB). This is also evidenced from the results that the seed germination parameters significantly differed among treatments, while seedling growth parameters did not exhibit significant difference indicating the less pronounced effect of application of chemicals and bio inoculants at one month after sowing.

TABLE 1: Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on germination efficacy

		Days taken for germination				Germination percentage (%)				Rate of emergence			
		CB_5	CB_7	Mean		CB_5	CB_7	Mean		CB_5	CB_7	Mean	
S_3	M_3	8.00	7.00	7.50		97.90	94.40	96.21		42.40	38.20	40.30	
	M_6	7.90	7.00	7.50	M_3-	97.40	96.60	97.24	M_3-	38.10	38.60	38.30	
Mean		8.00	7.00	S_3- 7.50	7.20	97.70	95.70	S_3- 96.70	95.50	40.30	38.40	S_3- 39.30	M_3- 39.00
S_5	M_3	7.00	7.00	7.00		93.10	96.60	94.80		37.20	38.20	37.70	
	M_6	8.00	7.00	7.50	M_6-	95.60	98.30	96.90	M_6-	37.60	42.00	39.80	
Mean		7.50	7.00	S_5- 7.20	7.50	94.30	97.40	S_5- 95.90	97.10	37.40	40.10	S_5- 38.70	M_6- 39.00
		CB_5 - 7.70	CB_7- 7.00		GM 7.30	CB_5- 96.00	CB_7- 96.50		GM9 6.30	CB_5- 38.80	CB_7- 39.20		GM 39.00

Interaction tables



		S	M	CB	S x M	M x CB	S x CB	S x M x CB
DTG	SE (d)	0.09	0.09	0.09	0.13	0.13	0.13	0.19
	CD	0.20*	0.20*	0.20*	0.28*	0.28*	0.28*	0.40*

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
GP	SE (d)	0.58	0.58	0.58	0.83	0.83	0.83	1.17
	CD	1.24**	1.24**	1.24*	1.76**	1.76NS	1.76NS	2.49NS

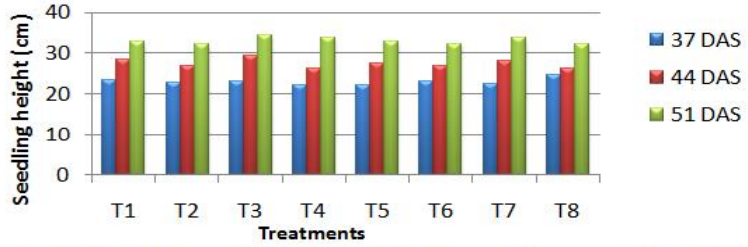
(DTG- days taken for germination; GP- germination percentage; RE-rate of emergence; GM- grand mean; NS-nonsignificant)

TABLE 2: Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on seedling height

		Seedling height at 37 DAS (cm)				Seedling height at 44 DAS (cm)				Seedling height at 51 DAS (cm)			
		CB_5	CB_7	Mean		CB_5	CB_7	Mean		CB_5	CB_7	Mean	
S_3	M_3	23.10	22.30	22.70		28.10	26.80	27.40		32.60	31.90	32.20	
	M_6	23.60	23.70	23.60	M_3- 7.20	29.20	26.00	27.60	M_3 27.20	34.10	33.50	33.80	
Mean		23.30	23.00	S_3- 23.20		28.60	26.40	S_3- 27.50		33.30	32.70	S_3- 33.00	M_3- 32.20
S_5	M_3	21.70	22.70	22.20		27.40	26.80	27.10		32.50	31.80	32.20	
	M_6	22.30	22.00	22.10	M_6- 7.50	27.70	26.00	26.80	M_6- 27.20	33.50	32.00	32.80	
Mean		22.00	22.30	S_5- 22.10		27.50	26.40	S_5- 26.90		33.00	31.90	S_5- 32.50	M_6- 39.00
		CB_5 7.70	CB_7- 7.00		GM 22.70	CB_5- 28.10	CB_7- 26.40		GM 27.26	CB_5- 33.20	CB_7- 32.30		GM 39.00

Interaction tables

Fig.2. Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on seedling height



T_3- $S_3M_3CB_5$ =KNO_3 @ 1.0 %+ Cocopeat + Vermicompost + *Pseudomonas fluorescens* + KH_2PO_4 @ 0.5 %;
T_7 - $S_5M_3CB_5$ = PPFM @ 2.0 %+ Cocopeat + Vermicompost + *Pseudomonas fluorescens* + KH_2PO_4 @ 0.5 %

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
37 DAS	SE (d)	0.13	0.13	0.13	0.19	0.19	0.19	0.27
	CD	0.29**	0.29**	0.29**	0.41**	0.41NS	0.41*	0.58**
		S	M	CB	S x M	M x CB	S x CB	S x M x CB
44 DAS	SE (d)	0.31	0.31	0.31	0.44	0.44	0.44	0.62
	CD	0.66NS	0.66**	0.66**	0.94NS	0.94*	0.94NS	1.33NS
		S	M	CB	S x M	M x CB	S x CB	S x M x CB
51 DAS	SE (d)	0.29	0.29	0.29	0.41	0.41	0.41	0.59
	CD	0.62NS	0.62**	0.62**	0.88**	0.88NS	0.88NS	1.25**

(DAS- days after sowing; GM- grand mean; NS-nonsignificant)

The number of days taken for germination did not differ significantly among the treatments. However, the treatment T_3 took the least days (7.0 days) for germination wherein seeds treated with KNO_3 at 1.0% for 12 hours (S_3), sown in potting media comprising of Cocopeat + Vermicompost + *Pseudomonas fluorescens* (M_3) and the seedlings were drenched with KH_2PO_4 @ 0.5%. Considering the two way interactions (S x M, M x CB, and S x CB), the effect of these three interactions was significant with respect to days taken for germination. Among the three factors, days taken for germination were significantly influenced by potting media. It might be due to the superiority of KNO_3 in enhancing seed germination and seedling vigour attributes was reported by Millaku *et al.* (2012) and Erken and Kaleci, (2010).

`The maximum germination percentage (98.30%) was recorded in T_6 ($S_5M_6CB_7$) where in the seeds treated with PPFM @ 2% for 12 hours (S_5) and sown in potting media M_6 and the seedlings drenched with PPFM @ 2.0% followed by T_3 ($S_3M_3CB_5$), wherein seeds were treated with KNO3 at 1.0% for 12 hours (S3) and sown in M3 potting media and applied with KH_2PO_4 @ 0.5 % at one month after germination). The increase in germination might also be due to the fact that coir dust (cocopeat) when mixed with organic manure improves the overall physical traits of the media (Garcia *et al*., 2002) which was confirmed in ornamentals (Van Holm, 1993). Vermicompost is reported to have bio active principles which are considered to be beneficial for root growth and results in higher germination, enhanced growth and development (Bachman and Metzger, 2008)

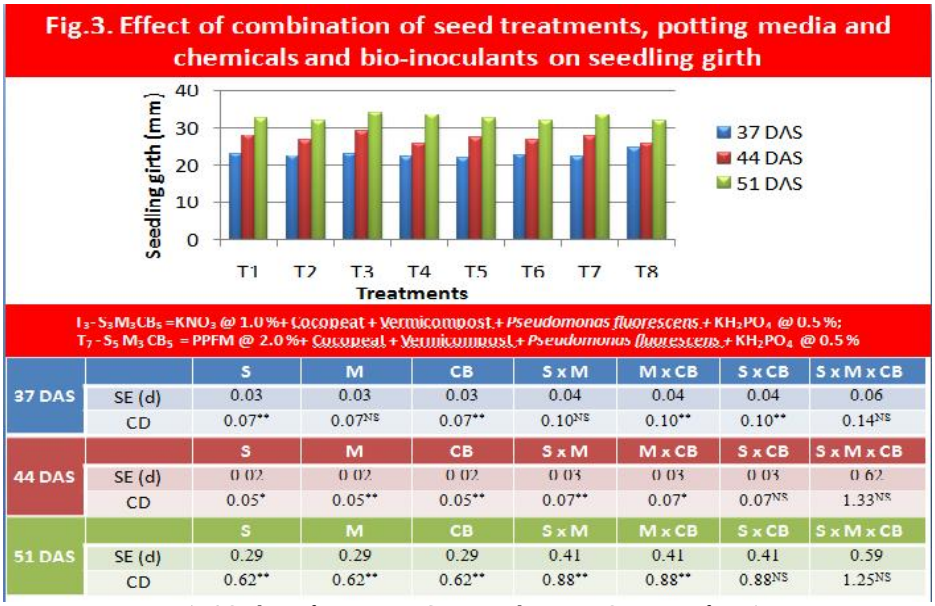
The seedling height statistically differed among the treatments. The highest seedling height was recorded in T_3 ($S_3 + M_3 + CB_5$), which were 23.61, 29.20 and 34.15 cm at 37, 44 and 51 days after sowing respectively. Considering the two way interactions among three factors viz., seed treatments (S), potting media (M), chemicals and bio-inoculants (CB), S x M alone was found to be significant, while S x CB and M x CB were found to be non significant. Three-way interaction of S x M x CB were found to be significant among the treatments. The three way interaction of S x M x CB indicated that they did not differ significantly among treatments. However, the highest seedling girth was recorded in T_3 ($S_3M_3CB_5$), which were 2.98, 3.56 and 4.07 mm at 37, 44 and 51 days after sowing respectively. Among the two way interactions S x M and M x CB were found to be significant. PPFM also increases the availability of growth regulators such as IAA and cytokinins (Omer *et al*., 2004; Madhaiyan *et al*., 2006 and Senthilkumar *et al*., 2009). The results obtained

also support the beneficial role of PPFM in imparting vigour in papaya seedlings. Many reports have indicated the importance of *Azospirillum* in perennial horticultural crops like banana (Jeeva, 1987) and papaya (Garcia *et al*., 2002).The presence of *Azospirillum* in the media helps in fixation of nitrogen and makes it available to the plant. This stimulated supply of nitrogen which would have played a key role in increasing synthesis of chlorophyll and amino acids subsequently into proteins and nucleic acids forming a framework for chloroplast there by better photosynthetic activity as suggested by Awasthi *et al.*(1996) while studying the interaction effect of VAM, Mycorrhizae and *Azotobacter* inoculation on peach seedlings.

TABLE 3: Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on seedling girth

		Seedling girth at 37 DAS (cm)				Seedling girth at 44 DAS (cm)				Seedling girth at 51 DAS (cm)			
		CB_5	CB_7	Mean		CB_5	CB_7	Mean		CB_5	CB_7	Mean	
S_3	M_3	2.80	2.60	2.70		3.10	3.00	3.00		3.10	3.00	3.00	M_3-
	M_6	2.90	2.60	2.80	M_3-	3.50	3.10	3.30	M_3-	3.50	3.10	3.30	3.10
Mean		2.90	2.60	S_3-	2.70	3.30	3.10	S_3-	3.10	3.30	3.10	S_3-	
				2.70				3.20				3.20	
S_5	M_3	2.50	2.80	2.60		3.00	3.10	3.10		3.00	3.10	3.10	
	M_6	2.70	2.60	2.60	M_6-	3.20	2.90	3.10	M_6-	3.20	2.90	3.10	
Mean		2.60	2.70	S_5-	2.70	3.10	3.00	S_5-	3.20	3.10	3.00	S_5-	M_6-
				2.60				3.10				3.10	3.20
		CB_5	CB_7-		GM	CB_5-	CB_7-		GM	CB_5-	CB_7-		GM
		2.70	2.60		2.70	3.20	3.00		3.10	3.20	3.090		39.00

Interaction tables



		S	M	CB	S x M	M x CB	S x CB	S x M x CB
37 DAS	SE (d)	0.03	0.03	0.03	0.04	0.04	0.04	0.06
	CD	0.07**	0.07NS	0.07**	0.10NS	0.10**	0.10**	0.14NS
		S	M	CB	S x M	M x CB	S x CB	S x M x CB
44 DAS	SE (d)	0.02	0.02	0.02	0.03	0.03	0.03	0.62
	CD	0.05*	0.05**	0.05**	0.07**	0.07*	0.07NS	1.33NS
		S	M	CB	S x M	M x CB	S x CB	S x M x CB
51 DAS	SE (d)	0.29	0.29	0.29	0.41	0.41	0.41	0.59
	CD	0.62**	0.62**	0.62**	0.88**	0.88**	0.88NS	1.25NS

(DAS- days after sowing; GM- grand mean; NS-nonsignificant)

TABLE 4: Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on vigour index and days taken to attain 15 cm height

		vigour index				Days taken to attain 15 cm height (cm)			
		CB_5	CB_7	Mean		CB_5	CB_7	Mean	
S_3	M_3	5309	5011	5160		28.45	28.96	28.70	
	M_6	5327	4847	5087	M_3-5108	27.74	28.60	28.17	M_3-29.19
Mean		5318	4929	S_3-5124		28.10	28.78	S_3-28.44	
S_5	M_3	5009	5101	5055		29.75	29.62	29.68	
	M_6	4970	5234	5102	M_6-5094	28.37	27.93	28.15	M_6-28.16
Mean		4990	5168	S_5-5079	GM	29.06	28.77	S_5-28.91	GM
		CB_5-5154		CB_7-5048	5101	CB_5- 28.58		CB_7- 28.77	28.68

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
Vigour index	SE (d)	60.54	60.54	60.54	85.61	85.61	85.61	176.83
	CD	128.34NS	128.34NS	128.34NS	181.50NS	181.50NS	181.50**	250.08NS
		S	M	CB	S x M	M x CB	S x CB	S x M x CB
15 cm height	SE (d)	0.31	0.31	0.31	0.44	0.44	0.44	0.93
	CD	0.66**	0.66*	0.66NS	0.93NS	0.93NS	0.93NS	1.29NS

The computed vigour index values were significant among treatments. The vigour index value recorded the highest (5327) in T_3 ($S_3M_3CB_5$) wherein, seeds treated with KNO_3 at 1.0% for 12 hours (S_3) and sown in M_3 potting media and drenched with KH_2PO_4 @ 0.5% at one old seedling stage. Considering the three factors, namely seed treatments, potting media and chemicals and bio-inoculants, the vigour index was significantly influenced by all the three factors. Among the two-way interactions S x CB alone was significant.

Days taken to attain 15 cm height of the seedling, the interaction effect of seed treatments (S), potting media (M), application of chemicals and bio inoculants (CB) did not exhibit significant differences among treatments with regard to days taken to attain 15 cm height of seedling. However, among the two way interactions S x M, M x CB and S x CB were also found to be non significant.

TABLE 5: Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on shoot parameters

		Shoot length (cm)				Fresh weight of the shoot (g)				Dry weight of the shoot (g)			
		CB_5	CB_7	Mean		CB_5	CB_7	Mean		CB_5	CB_7	Mean	
S_3	M_3	33.13	32.22	32.67		4.54	4.85	4.69		0.98	0.82	0.90	M_3-
	M_6	32.13	30.08	31.10	M_3-	5.02	4.92	4.97	M_3-	1.17	0.87	1.02	4.76
Mean		32.63	31.15	S_3- 31.89	32.33	4.78	4.88	S_3- 4.83	4.76	1.07	0.84	S3- 4.83	
S_5	M_3	32.59	31.40	31.26		4.92	4.75	4.83		1.12	0.96	1.04	
	M_6	30.40	33.36	31.72	M_6-	5.02	4.86	4.94	M_6-	1.15	0.82	0.98	
Mean		31.49	32.38	S_5- 31.94	31.49	4.97	4.80	S_5- 4.88	4.95	1.13	0.89	S5- 4.88	M_6- 4.95
		CB_5- 32.06		CB_7- 31.76	GM- 31.10	CB_5- 4.87		CB_7- 4.84	GM 4.8	CB_5- 1.10		CB_7- 0.86	GM 0.98

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
SL	SE (d)	0.23	0.23	0.23	0.33	0.33	0.33	0.47
	CD	0.50 ^{NS}	0.50 **	0.50 ^{NS}	0.71**	0.71**	0.71**	1.00**

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
FWS	SE (d)	0.04	0.04	0.04	0.06	0.06	0.06	0.09
	CD	0.09^{NS}	0.09^{NS}	0.09^{NS}	0.13^{NS}	0.13*	0.13**	0.18*

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
DWS	SE (d)	0.01	0.01	0.01	0.01	0.01	0.01	0.03
	CD	0.02**	0.02*	0.02**	0.03 **	0.03**	0.03^{NS}	0.69^{NS}

The significant differences were observed for shoot length, fresh and dry weight of the shoot among the treatments. The shoot length was the highest (33.36 cm) in T_6 ($S_5M_6CB_7$) while T_3 ($S_5M_3CB_5$) was on par with T_6. The fresh and dry weight of the shoot was the highest in T_3 ($S_3M_3CB_5$) which recorded 5.02 g and 1.17 g respectively while T_5 ($S_5M_6CB_5$) was on par with T_3. All the two way interactions were found to be significant, indicating the influence of seed treatments, potting media and chemicals and bio-inoculants application on shoot growth parameters.

TABLE 6: Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on root parameters

		Root length (cm)				Fresh weight of the root (g)				Dry weight of the root (g)			
		CB_5	CB_7	Mean		CB_5	CB_7	Mean		CB_5	CB_7	Mean	
S_3	M_3	21.00	20.24	20.62	M_3-	0.78	0.82	0.80		0.12	0.17	0.14	M_3-
	M_6	22.00	20.34	21.17	20.76	0.89	0.71	0.80	M_3-	0.33	0.15	0.24	0.16
Mean		21.50	20.29	S3-20.89		0.83	0.76	S_3- 0.80	0.80	0.22	0.16	S3- 0.19	
S_5	M_3	20.05	21.75	20.90		0.87	0.74	0.80		0.19	0.19	0.19	
	M_6	20.62	20.93	20.77	M_6-	0.89	0.82	0.85	M6-	0.15	0.24	0.19	
Mean		20.33	21.34	S5- 20.84	20.97	0.88	0.78	S_5- 0.83	0.83	0.17	0.21	S5- 0.19	M_6- 0.22
		CB_5- 20.92		CB_7- 20.81	GM20.8	CB_5- 0.85		CB_7- 0.77	GM 0.8	CB_5- 0.20		CB_7- 0.18	GM 0.19

Interaction tables

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
RL	SE (d)	0.23	0.23	0.23	0.33	0.33	0.33	0.47
	CD	0.50 **	0.50 **	0.50 **	0.71**	0.71**	0.71NS	1.01**

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
FWR	SE (d)	0.01	0.01	0.01	0.01	0.01	0.01	0.02
	CD	0.02**	0.02*	0.02**	0.03 **	0.03**	0.03^{NS}	0.04**

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
DWR	SE (d)	0.001	0.001	0.001	0.001	0.001	0.001	0.002
	CD	0.002^{NS}	0.002^{*}	0.002^{**}	0.003^{**}	0.003^{**}	0.003^{**}	0.005^{**}

The effect of combination of seed treatments, potting media, chemicals and bio-inoculants on root length, fresh and dry weight of the root showed significant differences among treatments. The root length, fresh and dry weight of the root was the highest in T_1 ($S_3M_6CB_5$) which recorded 22.0 cm, 0.89 g and 0.29 g respectively, while T_8 ($S_5M_3CB_7$) was on par with T_1. Among the two-way interactions S x M and M x CB were significant, while S x CB was found to be non significant.

TABLE 7: Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on leaf nutrient contents

		Nitrogen content (%)				Phosphorous content (%)				Potassium content (%)			
		CB_5	CB_7	Mean		CB_5	CB_7	Mean		CB_5	CB_7	Mean	
S_3	M_3	1.69	1.13	1.41		0.85	0.82	0.83		2.74	3.00	2.87	
	M_6	1.84	1.72	1.78	M_3-	0.97	0.78	0.87	M_3-	3.19	2.09	2.64	M_3-2.81
Mean		1.77	1.43	S_3-1.60	1.40	0.91	0.80	S_3-0.85	0.77	2.96	2.55	S_3-2.76	
S_5	M_3	1.03	1.76	1.39		0.75	0.69	0.72		2.67	2.85	2.76	
	M_6	1.21	1.69	1.45	M_6-	0.92	0.80	0.86	M_6-	2.75	3.13	2.94	M_6-2.79
Mean		1.12	1.72	S_5-1.42	1.62	0.83	0.74	S_5-0.79	0.86	2.71	2.99	S_5-2.85	
		CB_5-1.44	CB_7-1.58		GM 1.51	CB_5-0.87	CB_7-0.77		GM-0.82	CB_5-2.84	CB_7-2.77		GM 2.80

Interaction tables

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
N	SE (d)	0.01	0.01	0.01	0.01	0.01	0.01	0.02
	CD	0.02^{**}	0.02^{**}	0.02^{**}	0.04^{**}	0.04^{**}	0.04^{**}	0.05^{**}

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
P	SE (d)	0.008	0.008	0.008	0.01	0.01	0.01	0.01
	CD	0.01^{**}	0.01^{**}	0.01^{**}	0.02^{**}	0.02^{**}	0.02^{**}	0.03^{**}

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
K	SE (d)	0.02	0.02	0.02	0.03	0.03	0.03	0.05
	CD	0.05^{**}	0.05^{NS}	0.05^{*}	0.08^{**}	0.08^{**}	0.08^{**}	0.11^{**}

The statistical analysis on leaf nitrogen, phosphorous and potassium content clearly indicated that there existed significant difference among treatments. The highest nitrogen (1.84 %), phosphorous (0.97 %) and potassium content (3.19 %) were recorded in T_3 ($S_3M_3CB_7$) and T_8 ($S_5M_3CB_7$) was also on par with T_3.

Considering the two way interactions S×M, S x CB, M x CB were significantly differing in leaf nitrogen and potassium contents, whereas S x CB alone was significant for leaf phosphorous content.

TABLE 8: Effect of combination of seed treatments, potting media and chemicals and bio-inoculants on leaf chlorophyll and soluble protein contents

		Leaf chlorophyll content (mg gm^{-1})				Leaf soluble protein content (mg gm^{-1})			
		CB_5	CB_7	Mean		CB_5	CB_7	Mean	
S_3	M_3	2.28	2.21	2.25		63.24	51.61	57.42	M_3-53.22
	M_6	2.12	2.29	2.20	M_3-2.24	60.39	57.76	59.07	
Mean		2.20	2.25	S_3-2.22		61.82	54.68	S_3-58.25	
S_5	M_3	2.19	2.29	2.24	M_6-2.26	49.91	48.15	49.03	M_6-55.57
	M_6	2.31	2.32	2.31		53.00	51.12	S_5-52.06	
Mean		2.21	2.30	S_5-2.28		51.46	49.63	50.54	
		CB_5-2.22		CB_7-2.28	GM-2.25	CB_5-56.64		CB_7-52.16	GM-54.40

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
CC	SE (d)	0.01	0.01	0.01	0.02	0.02	0.02	0.03
	CD	0.03^{**}	0.03^{NS}	0.03^{**}	0.05^{**}	0.05^{*}	0.05^{NS}	0.07^{**}

		S	M	CB	S x M	M x CB	S x CB	S x M x CB
LSP	SE (d)	0.40	0.40	0.40	0.56	0.56	0.56	0.80
	CD	0.85^{**}	0.85^{**}	0.85^{**}	1.20^{NS}	1.20^{**}	1.20^{**}	1.70^{**}

The leaf chlorophyll content showed significant differences among treatments. The highest chlorophyll content (2.33 mg g^{-1}) was recorded in T_6 ($S_5M_6CB_7$) while T_5 was on par with T_6. Among the two way interactions, the combinations S x M and M x CB alone were found to be significant. The three way interaction too was found to be significant.

Leaf soluble protein content showed significant differences among treatments. The highest leaf soluble protein content (63.24 mg g^{-1}) was recorded in T_3 ($S_3M_3CB_5$). All the three and two way interactions exhibited significant differences on leaf chlorophyll content, except S x M interaction indicating the more pronounced effect of CB on leaf soluble protein content.

Plate a: Effect of combination of seed treatments, potting media, chemicals and bioinoculants on seed germination and seedling growth

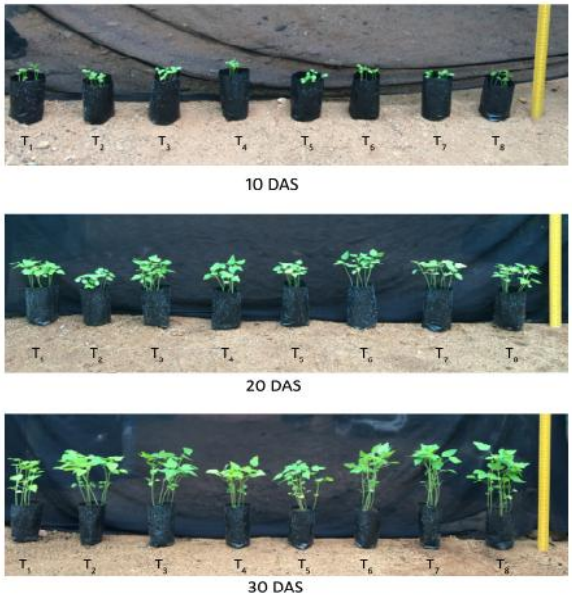


Plate b: Effect of seed treatments, potting media, chemicals and bioinoculants on seedling growth and vigour observed at weekly intervals

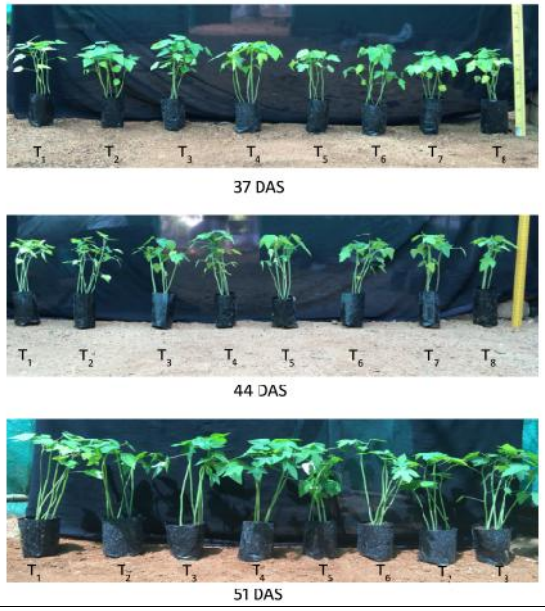


Plate c: Effect of seed treatments, potting media, chemicals and bioinoculants on root biomass

T_1: Seed soaking with KNO_3 1% for 12h + M_4 + Application of KH_2PO_4 0.5% @ 30 DAS
T_2: Seed soaking with KNO_3 1% for 12h + M_4 + Application of PPFM 2.0% @ 30 DAS
T_3: Seed soaking with KNO_3 1% for 12h + M_3 + Application of KH_2PO_4 0.5% @ 30 DAS
T_4: Seed soaking with KNO_3 1% for 12h + M_3 + Application of PPFM 2.0% @ 30 DAS
T_5: Seed soaking with PPFM 2% for 12h + M_4 + Application of KH_2PO_4 0.5% @ 30 DAS
T_6: Seed soaking with PPFM 2% for 12h + M_4 + Application of PPFM 2.0% @ 30 DAS
T_7: Seed soaking with PPFM 2% for 12h + M_3 + Application of KH_2PO_4 0.5% @ 30 DAS
T_8: Seed soaking with PPFM 2% for 12h + M_3 + Application of PPFM 2.0% @ 30 DAS

CONCLUSION

It was concluded from the study that the treatment T_3 (S_3+M_3+CB_5), wherein the seeds treated with KNO_3 @ 1.0% for 12 hours (S_3), sown in potting media comprising of Cocopeat + Vermicompost + *Pseudomonas fluorescens* (M_3) + drenching the seedlings with KH_2PO_4 1.0% at one month after sowing (T_3) was adjudged as the best for improvement of seed germination, seedling growth and vigour.

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