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Nutrient based seed coating formulation for enhancement of seed germination characteristics, crop growth and productivity of cotton

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A B S T R A C T

Seed coating polymer is a product in which additives are dissolved or dispersed in a liquid adhesive, usually a dyed solution of a polymer, into which the seeds are dipped or sprayed before drying. The objective of the present study was thus to develop a 'seed coating polymer formulation' and standardize the optimum dosage for coating of seeds and assess their effect on seed germination and plant growth characteristics of cotton. The seed coating polymer formulation was developed by mixing ingredients such asMurashige and Skoog medium, carboxy methyl cellulose, gelatin, glycerol, bone meal, dicalcium phosphate and pectin in appropriate quantities along with optimum quantities of synthetic polymer, pigment and water. The formulation was used for coating seeds in three different dosages such as 20, 30 and 40 g Kg^{-1} of seeds and assessed for effect on seed germination characteristics as well as initial seedling vigour in nursery bed laid in a shade house. The effect on plant growth and productivity was evaluated by adopting a field trial in randomized block design. The observations were made on various growth and yield attributes. The results revealed a gradual increase in all the seed germination characteristics observed, as the dosage increased. The final seed yield recorded (Kg $plot^{-1}$) and 100 seed weight (g) was also found to be highest when the cotton seeds were treated with 40 g kg^{-1} as it recorded 116.84 and 15.25 per cent increase over control and 44.05 and 12.84 per cent increase over 30 g kg^{-1}. The results of the present experiment brought out the positive impact of seed coating polymer formulation on plant growth, chlorophyll content, branching pattern, boll yield, seed yield and 100 seed weight in all the dosages experimented *viz.*, 20, 30 and 40 g kg^{-1} , however the highest improvement was recorded in 40 g kg^{-1}. The crop growth and yield improvement is attributed to the increased activity of rhizosphere microorganisms and eventual increase in mobilization of nutrients to the plants resulting in enhanced crop growth and productivity.

Introduction

The seed is the generative dispersal unit, which enables plants to spread and survive through periods or seasons of less favourable conditions. High quality seed is the key for successful agriculture.

Uniformity in growth and synchrony in development are highly desirable characters for mechanized cultural operations. For any crop the time from sowing to seedling establishment is a crucial period during which the seed is exposed to a wide range of environmental stress that can adversely affect its performance.

Seed invigouration treatments are aimed at increasing the seed germination potential as well as seedling vigour. Invigorated seeds germinate rapidly and vigourously and are more likely to produce vigourous seedlings in field conditions (Aldhous, 1972). Increased speed of mergence, helps to shorten the time of exposure of juvenile seedlings to biotic and abiotic stress, thereby enabling successful plant establishment and better plant growth.

Film coating is as the process in which additives are dissolved or dispersed in a liquid adhesive, usually a dyed solution of a polymer, into which the seeds are dipped or sprayed before drying (Halmer, 1987). The seed film coating should be more or less continuous to eliminate or minimize product dustoff, as low dust-off is an important factor in worker safety (Taylor *et al.*, 2001). Polymer film coating is also seen a technology to encapsulate seeds with beneficial organisms (Rhizobia and other biologicals) on various crop seed (Burris, 1992; Devay *et al.*,1991).

Devay *et al.* (1991) found polymers to be effective carriers for applying biological control agents in cotton, with the polymers providing enough protection to sustain effective biological control for up to four months.

Kaufman (1991) suggests that the "ideal" coating would be neutral in its influence on the speed, uniformity and germination percentage of a seed lot. A better definition of an ideal coating might include a coating which would be neutral or have a beneficial influence on the speed, uniformity and germination percentage. John *et al.* (2005) emphasized that, since the seed coatings are extremely thin, multiple coatings of various ingredients are also possible. This advanced technology allows the application of combinations of nutrients, fungicides, insecticides, herbicides and beneficial microorganisms to seed (Nascimento *et al.*, 1993).

Owing to exploit the polymer film coating technology to improve the seed germination and seedling vigour potential of the seeds, it is quintessential to add the potential nutrient sources as additivies to the seed coating polymer. Popular nutrient sources are Murashige and Skoog medium (Murashige and Skoog, 1962), carboxy methyl cellulose (Ido and Susno, 1990), gelatin (Takahashi and Trias, 2012), glycerol (Stobart *et al.*, 1970), bone meal (Chaves *et al.*, 2005), dicalcium phosphate (Chitralekha and Ken, 2004), pectin (Anupama *et al.*, 2011), sucrose (Eastmond, 2006), asparagines (Wilson, 1986) and peptone (Oliva and Arditti, 1984).

With the above views in mind, a research investigation was formulated to develop a polymer seed coating formulation with appropriate nutrient mixture and pigment amenable for seed coating purposes.

Materials and Methods

Genetically pure, cotton seeds var. MCU 12 (*Gossypium hirsutum* L.) was obtained from Department of Cotton, Tamil Nadu Agricultural University, Coimbatore. Synthetic polymers and pigment obtained from Sudarshan General Traders, Sivakasi, served as the base material for preparing the seed coating polymer formulation. The composition standardized through preliminary experiments were mixed and homogenized to produce the new ‘Seed Coating Polymer” formulation. The final composition of the seed coating polymer consisted on Murashige and Skoog medium, carboxy methyl cellulose, gelatin, glycerol, bone meal, dicalcium phosphate, pectin, polymer, pigment and water.

The newly developed seed coating polymer formulation comprising of polymer, nutrient mixture and pigment was taken up for coating of cotton seeds in three dosages listed below

T_0- Control
T_1- 20 g kg^{-1} of seeds
T_2 - 30 g kg^{-1} of seeds
T_3 - 40 g kg^{-1} of seeds

The seeds coated with the newly developed seed coating polymer formulation were estimated for wet weight and dry weight of coated seeds prior to taking up of sowing. Cotton seeds subjected to seed coating with seed coating polymer were sown in nursery beds prepared in shade house and watered regularly on daily basis. The experiment was laid in completely Randomized design. Observations were made on days to initial germination, days for 50% germination, days for maximum germination, speed of germination, germination, root length, shoot length, Vigour index II and dry matter production (ISTA, 2013).

Subsequently, coated seeds were sown in field by following Randomized Block Design with 5 replications. The crop was grown by following recommended package of practices. During the crop growth period, periodically ten plants in each replication and treatments were randomly selected for recording the growth parameters *viz.*, root volume $plant^{-1}$, plant height (cm), number of leaves $plant^{-1}$, leaf area $plant^{-1}$, chlorophyll content, number of sympodia $plant^{-1}$, number of monopodia $plant^{-1}$, number of squares $plant^{-1}$, number of bolls $plant^{-1}$,100 seed weight, seed yield $plot^{-1}$ and seed yield ha^{-1}.

Statistical Procedures

Data were analyzed using an analysis of variance (ANOVA) as a factorial combination of treatments. Means were separated on the basis of least significant difference (LSD) only if F test of ANOVA for treatments was significant at the 0.05 or 0.01 probability level. Values in percent data were arcsine transformed before analysis.

Results and Discussion

The results of the experiment conducted to standardize the optimum dosage of the newly developed seed coating formulation are discussed hereunder. With respect to cotton, among the three dosages *viz.*, 20, 30 and 40 g kg^{-1}, highest wet weight (51.9248 g) and dry weight (51.584 g) was recorded in 40 g kg^{-1}. The seed germination characteristics was found to register a gradual increase in all the parameters observed, as the dosage of seed coating increased. The highest level of days for initial germination (3.9), days for 50 % germination (4.7), days to maximum germination (6.3), speed of germination (17.584) and germination (83 %) were observed in 40 g kg^{-1}. The same dosage also recorded highest values for root length (23 cm), shoot length (46.40 cm), vigour index I (5690), at 50 DAS. Vigour index II (142553), dry matter production (1717.5 g 10 $seedlings^{-1}$), root volume (21.08 cc $seedling^{-1}$) at maturity stage, which was 20.04, 60.55, 44.42, 232.62, 216.59 and 278.46 percentage higher than control (Table 1, 2).

The observations recorded on plant height (cm), no. of leaves $plant^{-1}$, leaf area $plant^{-1}$ (cm) and chlorophyll content at maturity stage revealed that there was 54.98, 156.52, 284.65 and 53.54 per cent increase over the control. The number of symbodial branches $plant^{-1}$, number of monopodial branches $plant^{-1}$, no. of squares $plant^{-1}$, no. of bolls $plant^{-1}$ recorded at vegetative, flowering and maturity stages also revealed the superiority of 40 g kg^{-1} (Table 3, 4).

The final seed yield recorded (kg $plot^{-1}$) and 100 seed weight (g) was also found to be highest when the cotton seeds were treated with 40 g kg^{-1} as it recorded 116.84 and 15.25

per cent increase over control and 44.05 and 12.84 per cent increase over 30 kg ha^{-1}. The results of the present experiment clearly brought out the seed coating polymer formulation was effective in increasing plant growth, chlorophyll content, branching pattern, boll yield, seed yield and 100 seed weight in all the dosages experimented *viz.*, 20, 30 and 40 g kg^{-1} , however the highest improvement was recorded in 40g kg^{-1}(Table 5).

Zelonka (2005) reported that treatment of seeds with phosphorus effected positively the physiological activity of the next generation seeds: increased seed germination and germination power, and higher concentrations of chlorophyll and carotenoids in the shoots. The early vigour of barley seedlings was ensured by promotion of the formation of photosynthetic pigments and accordingly, higher rates of photosynthesis. This apparently supported for future development, as shown by an increase of grain yield. Other studies have described an increase in dry matter and the amount of tillers which may be consequence of increased photosynthesis and photosynthate production (Scott *et al.* 1985).

In the present experiment, it was hypothesized that since the seed coating formulation contains substances such as bone meal and dicalcium phosphate, it could have helped in increasing the rhizosphere micro organisms, which would have increased the plant growth and yield attributing factors. Therefore, an analysis was made to estimate the population of bacteria, fungi and actinomycetes population in rhizosphere. The results revealed that significantly higher population of bacteria, fungi and actinomycetes were present when seeds were coated with 20, 30 and 40 g kg^{-1}. However, highest level of bacteria (90), fungi (2) and actinomycetes (41) were observed in 40 g kg^{-1}(Table 6).

Randy *et al.* (2009) A wide range of microorganisms found in the rhizhosphere are able to produce substances that regulate plant growth and development of plant. Bacterial and fungal production of phytohormones such as auxins and cytokinins can affect cell proliferation in the shoot leading to tumorous growth of plants.Micro organisms can affect plant growth by different direct and indirect mechanisms (Glick, 1995; Gupta *et al.*, 2000). Some examples of these mechanisms, which can probably be active simultaneously or sequentially at different stages of plant growth, are (1) increased mineral nutrient solubilization and nitrogen fixation, making nutrients available for the plant; (2) repression of soilborne pathogens (by the production of hydrogen cyanide, siderophores, antibiotics, and/or competition for nutrients); (3) improving plant stress tolerance to drought, salinity, and metal toxicity; and (4) production of phytohormones such as (IAA) indole-3-acetic acid.

Microbial communities are known to respond organic matter amendments with increased activity and growth, which affects soil processes, including nitrogen mineralization (Fauci and Dick, 1994). Organic manures usually increase the soil microbial biomass (Parham *et al.*, 2002; Peacock *et al.*, 2001), CO_2 evolution (Ajwa and Tabatabai, 1994) and enzyme activities (Crecchio *et al.*, 2001; Kandeler *et al.*, 1999). Soil microbial biomass C/N is variable depending on the composition of microbial population, but there is a general consensus to a mean value at around 8 (Kuzyakov *et al.*,(2000); Murphy *et al.*, (2003). This value is higher than the C/N ratio of MBM (Meat and Bone Meal) and this implies that microbial utilization of MBM would lead to the liberation of mineral N in the soil and this release would be higher with increasing C/N ratio in the soil microbial biomass.

Table.1 Effect of seed coating polymer formulation on seed germination characteristics of cotton var. MCU 12

Treatment	Seed wet weight (g)	Seed Dry weight (g)	Days for initial germination	Days for 50% germination	Days for maximum germination	Speed of germination	Germination (%)
Control	50.000	50.0000	4.2	5.0	6.5	15.51	79 (62.72)
20g kg^{-1}	50.9477	50.0469	4.0	4.9	6.5	15.53	81 (64.15)
30g kg^{-1}	51.3280	51.0913	4.0	4.9	6.4	16.04	84 (66.42)
40g kg^{-1}	51.9248	51.5841	3.9	4.7	6.3	17.58	83 (65.65)
Mean	**51.0501**	**50.6806**	**4.0**	**4.9**	**6.4**	**16.17**	**82 (64.89)**
SEd	0.4531	0.4771	0.02	0.02	0.06	0.13	0.50
CD(P=0.05)	0.9606	1.0115	0.05	0.04	0.13	0.29	1.09

(Figures in parenthesis indicate arcsine values)

Table.2 Effect of seed coating polymer formulation on seedling vigour of cotton var. MCU 12

Treatment	Root length (cm)	Shoot length (cm)	Vigour index I	DMP (g 10 seedlings^{-1})		Vigour index II		Root volume (cc seedling^{-1})	
	(50 DAS)			Vegetative stage (60 DAS)	Maturity stage (120 DAS)	Vegetative stage (60 DAS)	Maturity stage (120 DAS)	Vegetative stage (60 DAS)	Maturity stage (120 DAS)
Control	19.16	28.90	3940	33.87	542.5	2676	42858	1.14	5.57
20g kg^{-1}	21.64	42.50	5259	76.08	907.5	6162	73508	2.84	12.31
30g kg^{-1}	23.30	42.94	5431	97.18	1182.5	8163	99330	3.50	15.10
40g kg^{-1}	23.00	46.40	5690	111.89	1717.5	9287	142553	5.12	21.08
Mean	**21.78**	**40.19**	**5080**	**79.76**	**1087.5**	**6572**	**89562**	**3.15**	**13.51**
SEd	0.21	0.55	49.68	0.60	14.12	106.14	820.74	0.04	0.16
CD(P=0.05)	0.46	1.21	108.25	1.30	30.75	231.25	1788.20	0.09	0.35

Table.3 Effect of seed coating polymer formulation on morphological characteristics of cotton var. MCU 12

Treatment	Plant height plant^{-1}(cm)			No. of leaves plant^{-1}			Leaf area plant^{-1} (cm^2)		
	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Maturity stage (120 DAS)	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Maturity stage (120 DAS)	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Maturity stage (120 DAS)
Control	39.00	54.00	76.40	16.00	30.60	46.00	296.30	648.43	539.15
20g kg^{-1}	50.71	80.00	101.40	20.00	45.20	73.00	887.47	1843.18	1609.58
30g kg^{-1}	61.00	97.50	108.00	24.00	69.40	108.00	905.98	2162.53	1817.82
40g kg^{-1}	68.86	109.00	118.40	29.00	99.40	118.00	953.94	2418.20	2073.86
Mean	**54.89**	**85.13**	**101.05**	**22.25**	**61.15**	**86.25**	**760.92**	**1768.08**	**1510.10**
SEd	0.41	0.41	0.95	0.31	0.32	1.28	9.96	16.35	14.64
CD(P=0.05)	0.90	0.90	2.06	0.67	0.70	2.78	21.70	35.62	31.90

Table.4 Effect of seed coating polymer formulation on morphological and flowering characteristics of cotton var. MCU 12

Treatment	Chlorophyll content			No. of Sympodial plant^{-1}			No. of Monopodial plant^{-1}		
	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Maturity stage (120 DAS)	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Maturity stage (120 DAS)	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Maturity stage (120 DAS)
Control	22.16	20.00	20.06	4	7	10	2	2	2
20g kg^{-1}	29.05	24.27	24.06	5	10	14	2	2	2
30g kg^{-1}	31.97	29.54	29.03	6	13	14	2	2	2
40g kg^{-1}	35.55	31.70	30.80	7	15	15	1	1	1
Mean	**29.68**	**26.38**	**25.99**	**6**	**11**	**13**	**2**	**2**	**2**
SEd	0.34	0.29	0.36	0.03	0.10	0.21	0.17	0.17	0.17
CD(P=0.05)	0.74	0.63	0.78	0.06	0.21	0.46	0.38	0.38	0.38

Table.5 Effect of seed coating polymer formulation on yield attributing characters of cotton var. MCU 12

Treatment	No. of Squares plant^{-1}			No. of Bolls plant^{-1}		100 seed weight (g)	Seed yield (kg plot^{-1})	Seed yield per ha. (q)
	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Maturity stage (120 DAS)	Flowering stage (90 DAS)	Maturity stage (120 DAS)			
Control	4	10	4	3	11	7.4350	0.190	11.88
20g kg^{-1}	7	19	7	4	19	7.5424	0.230	14.38
30g kg^{-1}	9	24	2	10	19	7.5933	0.286	17.88
40g kg^{-1}	13	37	3	16	30	8.5690	0.412	25.75
Mean	**8**	**23**	**4**	**8**	**20**	**7.7849**	**0.280**	**17.47**
SEd	0.12	0.32	0.07	0.12	0.19	0.0294	0.001	2.06
CD (P=0.05)	21.70	35.62	31.90	0.26	0.43	0.0640	0.003	4.50

Table.6 Effect of seed coating polymer formulation on rhizosphere microorganisms in cotton var. MCU 12

Treatment	Bacteria ($X10^5$ CFU/g of soil)	Fungi ($X10^4$CFU/g of soil)	Actinomycetes ($X10^5$ CFU/g of soil)
Control	---	---	15
20g kg^{-1}	---	5	10
30g kg^{-1}	68	2	16
40g kg^{-1}	90	2	41
Mean	**40**	**2**	**21**
SEd	0.055	0.11	0.14
CD(P=0.05)	0.12	0.24	0.30

(Square root transformed values are used for analysis)

Addition of MBM in soil caused an overall and significant increase in the size of soil microbial biomass, in agreement with the general behaviour recorded after soil application of MBM (Novelo *et al.*,1998).A potential concern of soil application of MBM is represented by the high content of lipids. Lipids in the soil are known to have the potential for altering soil physical properties such as the degree of wetting (Dinel *et al.*, 1990; Stevenson, 1994). On the other hand there are studies that refer the ability of microorganisms to degrade lipids and to utilize them as source of C (Dinel *et al.*, 1990; Hita *et al.*, 1996). Moucawi *et al.*, (1981) reported high rates of decomposition of C-18 lipids in soils where the microbial populations were abundant and diversified, regardless of the chemical structure of the lipids. According to Jones (1998) the lack of phosphorus can increase the production of organic acids from the roots, amplifying consequently the growth and activity of micro-organisms in the rhizosphere (Toal *et al.*, 2000).

According to Vessey (2003), numerous species of soil bacteria which flourish in the rhizosphere of plants, but which may grow in, on, or around plant tissues, and stimulate plant growth by a plethora of mechanisms are collectively known as PGPR. Tomato growth was observed to be significantly improved with the antagonistic *Streptomyces* spp. as a seed-coating. An increased availability of growth regulators produced by the inoculums was the reason for the improvement in tomato growth, although this was not formally tested (El-Abyad *et al.*,1993). The production of plant growth hormones that improve root surface area may improve the ability of the plant to absorb these and other nutrients from the rhizosphere (Khalid *et al.*, 2004).

It is concluded that, the newly developed seed coating polymer formulation was very effective in improving the plant growth parameters as well as yield attributing factors in cotton, prominently by improving the activity of rhizosphere microorganisms, which could have significantly increased the mobilization of nutrients to the growth plants eventually resulting in higher crop productivity.

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