The Pharma Innovation Journal 2023; 12(7): 1702-1708

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(7): 1702-1708

www.thepharmajournal.com
Received: 11-05-2023
Accepted: 14-06-2023

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Augmenting the productivity of maize (*Zea mays* L.) through designer seed

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Abstract
The field experiment was conducted at National Seed Project, UAS, GKVK, Bangalore during Rabi-Summer, 2019-2020 to know the influence of designer seed on seed quality, crop performance and seed yield in maize. Experiment was laid out in randomized complete block design (RCBD) with three replications consisting nine treatment combinations. The results revealed that, all the pelleting treatments for designing the seed has enhanced the crop performance and seed yield. Among the treatments, seeds pelleted with Polymer @ 4.0 ml/kg + Metalaxyl @ 3.0 g/kg + (Cyantraniliprole + Thiamethoxam) @ 4.0 ml/kg + Zinc @ 2.0 g/kg + Atrazine @ 10 g/kg+ *Azotobacter chroococcum* @ 2 g/kg seeds (T_5) recorded less seed mycoflora (2.00%), plant height at 15, 30, 60 DAS and harvest (21.08 cm, 57.02 cm, 132.31 cm and 211.41 cm respectively), number of leaves per plant at 30, 60 DAS and harvest (6.73, 11.53 and 13.73 respectively) and took least days to initiation of 50% tasseling (54.93), least days for.50% silking (58.07), higher cob length (19.86cm), number of cobs per plant (1.53), 100 seed weight.(35.97g), cob dry weight (317.53 g) and seed yield per hectare (107.59 q) with cost-benefit ratio of 1:2.69.

Keywords: Maize, designer seed, seed pelleting, polymer, *Azotobacter*, seed mycoflora, B: C ratio

Introduction
Maize (*Zea mays* L.) is one of the most important cereal crops of *Poaceae* family and stands first with respect to production in the world. In India, it ranks third position after rice and wheat. The importance of maize usually lies in its wide industrial applications besides serving as human food and animal feed too. Maize is the most versatile-crop with greater adaptability in various agro-ecologies and it also has highest genetic yield potential among the food grain crops in world. Maize being a C_4 plant is capable of utilizing radiant energy and has highest capacity to generate carbohydrates per day as compared to the other cereal crops. The crop is less susceptible to environmental hazards and cost of production per kg grain is less compared to other cereal crops. Maize grain contains 10% protein, 3.4% fat, 4-5% oil, 1.1% ash, 1% starch fibre, 0.3% thiamine, 0.08% riboflavin and 1.9% niacin and in India about 35% of the maize grain is produce utilized for the consumption of human being, 25% each is used in poultry and the cattle feed and around 15% is used in food processing industries.

In world, it is grown in an area of 193.73 m ha with annual production of 1147.62 m MT with a productivity of 5.92 t ha^{-1} (Anon., 2021) [2-3] and the major maize producers are USA (32.61%), followed by China (22.91%), Brazil (9.42%), European Union (8.41%), Argentina (5.41%) and India (4.1%). In India, currently, maize is cultivated in an area of 9.86 m ha with the production of 31.51 m MT and with the productivity of 3.19 t ha^{-1} (Anon., 2021) [2-3]. The major important maize growing states in India are Madhya Pradesh (1.353 m ha), Karnataka (1.32 m ha), Rajasthan (0.86 m ha), Uttar Pradesh (0.72 m ha), Bihar (0.67 m ha), Telangana (0.63 m ha), Gujarat (0.40 m ha), Andhra Pradesh (0.33 m ha) and Punjab (0.11 m ha). In Karnataka, maize is grown in an area of 1.68 m ha with a production of 5.18 m MT and a productivity of 3.09 t ha^{-1}.

Maize is called "Queen of cereals" as it is grown throughout the year because of its photo and thermo-insensitive characters and having highest genetic-yield potential among the cereal crops. In India, maize is cultivated throughout the year in most of the states for different purpose including food grain, feed, young cobs, fodder, baby corn, sweet corn, popcorn and also industrial products. However, insects-pests, weeds and disease attack at different stage of crop from the time of sowing to maturity possess a serious damage in getting expected yield. The multiple pests complex of maize crop also possess serious limitation in the maize cultivation in various agro-climatic regions of India. Out of all the pests causing different degree of damage to maize, only a dozen pests are quite serious and they need to be controlled

(Shwetha, 2019) [15].

Among all the pest that attack maize, fall armyworm (*Spodoptera frugiperda*), *Chilo partellus*, *Sesamia inferens*, *Helicoverpa armigera*, *Atherigona soccata*, Bihar hairy caterpillar, leafhoppers, aphids, semilooper are having major importance during various seasons in India (Kumar *et al.*, 2005) [10]. Maize is also attacked by the several diseases like downey mildew, southern corn leaf blight, common rust, head smut and ear rot. Some of the common weeds of maize are *Parthenium hysterophorus*, *Acalypha indica*, *Corchorus olitorius*, *Amaranthus viridi* and *Euphorbia prostrate* which intern reduces the expected yield.

The successful development and establishment of the crops mainly depends on good quality seeds. To provide better quality seeds, many seed companies and researchers have developed designer seed through a new technology called "Seed Enhancement Techniques". The treatment of seed with bio agents is safe, economical, eco-friendly, cheap, can be done easily with locally accessible materials and non-harmful to seed, animals and human beings. The increase in seed yield and the quality seeds can be achieved by treating the seeds with fungicides, insecticides, bio agents, polymers and storing them under ambient conditions with minimum qualitative and quantitative changes.

Seed pelleting is one another physical pre-sowing seed-enhancement process of covering the seed with little quantity of inert-material, just large enough to produce globular unit to facilitate the precision planting and to enhance the seed-soil interface at the rhizosphere region. The inert material creates the natural water holding medium and provides little amount of nutrients to younger seedlings for their growth (Roos, 1979, Scott, 1989 and Krishnasamy, 2003) [12, 14, 9]. Most of the agricultural and horticultural crops are affected by insect-pests and diseases that cause significant economic damage. Therefore, treating seeds with plant protectant chemicals *viz.*, fungicides, insecticides, bio-fertilizers and weedicides prevents the losses caused to agricultural and horticultural crops by disease, pests and weeds.

Designer seed is an integrated pre-sowing seed enhancement technique that involves addition of nutrients, plant protectants, bio inoculants and also herbicides to enhance seed quality *viz.*, field emergence and yield attributing parameters. There are some benefits of designer seeds, such as enhanced germination and field emergence, improved seedlings vigour, sustained protection against diseases and pests during early growth period which intern reduce the plant protection cost and increased yield (Anon., 2016) [1]. Development of designer seeds in maize may help to improve field establishment and finally the productivity by reducing usage of more of plant protection chemical (Herbicides/ insecticides/fungicides). The aim of present study is to evaluate crop performance, disease, pests and weeds incidence and to assess the cost-benefit ratio of designer seed.

Material and Methods

Location of the experimental site

The field experiment was conducted at, Seed Technology Research Unit, J-Block, National Seed Project (Crops), University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru during December 2019 to April 2020. Experimental site was situated between 13° 05' N latitude and 77° 34' E longitude at an altitude of about 924 m above mean sea level (MSL).

Soil characters

Experimental plot selected was reddish brown lateritic soil derived from genesis under sub-tropical semi-arid climate. The physical and chemical properties of experimental site analyzed from composite sample collected from 0 to 30 cm depth from each plot in different treatments. Air dried soil sample was powdered and allowed to pass through 2 mm sieve and initial fertility status of soil in field was analyzed. The elaborated fertility level of macro, micro nutrient and pH are depicted in the appendix-I.

Weather conditions prevailed during cropping period

The data on climatic parameters such as maximum and minimum temperature (°C), rainfall (mm) and relative humidity (%) were recorded at meteorological observatory, Dryland Agricultural Project, University of Agricultural Sciences, GKVK, Bengaluru, during cropping period is depicted in appendix-I.

Experimental details

Source of seeds

The quality seeds of single cross hybrid Hema were obtained from National Seed Project, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru and seed material was dried to safe level of moisture and the previous crop grown in the selected experimental site was Proso millet during *Kharif*-2018.

Description of hybrid used in the experiment

The maize hybrid Hema was selected based on the duration of maturity and local adaptation. It can be grown in all the seasons (May-June, September-October and January-February). It is a single cross hybrid between NAI-137 (female parent) and MAI-105 (male parent). Its duration is 110-120 days and can grow up to 180-210 cm. Ears are cylindrical in shape with yellow colour. It gives around 36-38 q/acre grain yield.

Plan and layout of the experiment

The experiment was conducted during *Rabi-kharif*-2019-20 with twenty seven treatment combinations, laid out in randomized complete block design with three replications. The details of the experiment are outlined below and the treatments included in the experiment were mentioned in Table 1.

Location: NSP, UAS, GKVK, Bangalore
Crop: Maize
Hybrid: Hema
Season: *Rabi-Summer* (2019-2020)
Design: Randomized Complete Block Design
Treatments: 9
Replications: 3
Gross plot size: 3.6 m x 3.9 m
Net plot size: 3.5 m x 3.8 m

Table 1: Treatment details of the experiment

T_1	**Control**
T_2	Polymer @ 4.0 ml kg^{-1} + Metalaxyl @ 3.0 g kg^{-1}+(Cyantraniliprole +Thiamethoxam) @ 4.0 ml kg^{-1} + DAP @ 4.0 g kg^{-1} + Zinc @ 2.0 g kg^{-1} + Atrazine @ 10 g kg^{-1} seeds
T_3	Polymer @ 4.0 ml kg^{-1} + Metalaxyl @ 3.0 g kg^{-1} + (Cyantraniliprole +Thiamethoxam) @ 4.0 ml kg^{-1} + DAP @ 4.0 g kg^{-1} + Zinc @ 2.0 g kg^{-1} + *Azotobacter chroococcum* @ 2g kg^{-1} seeds
T_4	Polymer @ 4.0 ml kg^{-1} + Metalaxyl @ 3.0 g kg^{-1} + (Cyantraniliprole + Thiamethoxam) @ 4.0 ml kg^{-1} + DAP @ 4.0 g kg^{-1} + Atrazine @ 10 g kg^{-1}+ *Azotobacter chroococcum* @ 2g kg^{-1} seeds
T_6	Polymer @ 4.0 ml kg^{-1} + Metalaxyl @ 3.0 g kg^{-1} + DAP @ 4.0 g kg^{-1} + Zinc @ 2.0 g kg^{-1} + Atrazine @ 10 g kg^{-1}+ *Azotobacter chroococcum* @ 2g kg^{-1} seeds
T_7	Polymer @ 4.0 ml kg^{-1} + (Cyantraniliprole+Thiamethoxam) @ 4.0 ml kg^{-1} + DAP @ 4.0 g kg^{-1} + Zinc @ 2.0 g kg^{-1} + Atrazine @ 10 g kg^{-1}+ *Azotobacter chroococcum* @ 2g kg^{-1} seeds
T_8	Metalaxyl @ 3.0 g kg^{-1} + (Cyantraniliprole+Thiamethoxam) @ 4.0 ml kg^{-1} + DAP @ 4.0 g kg^{-1} + Zinc @ 2.0 g kg^{-1} + Atrazine @ 10 g kg^{-1} + *Azotobacter chroococcum* @ 2g kg^{-1} seeds
T_9	Polymer @ 4.0 ml kg^{-1} + DAP @ 4.0 g kg^{-1} + Zinc @ 2.0 g kg^{-1} + Atrazine @ 10 g kg^{-1} + *Azotobacter chroococcum* @ 2g kg^{-1} seeds

Procedure for pelleting to design designer seed was as follows

1. Pan coater or rotary coater was started. Required quantity of seeds were added into rotating pan coater and rotated for 2-3 minutes to remove dust particles from seed.
2. Little amount of water was added to make the seed bit wet and added pelleting powder (Easy Pel powder) material a single layer and required diluted amount of binder onto the seed.
3. After, recommended dose of metalaxyl (fungicide) was added to the wet seed uniformly and again added binder until the pellets become saturated wet, then added Easy Pel powder.
4. After reaching all the pellets to the size of 3.25 mm, later added recommended quantity of Fortenza Duo (Cyantraniliprole +Thiamethoxam), binder, and Easy Pel powder up to 3.5 mm size is reached.
5. This procedure was repeated for other components like DAP, zinc, atrazine, *Azotobacter* and polymer.

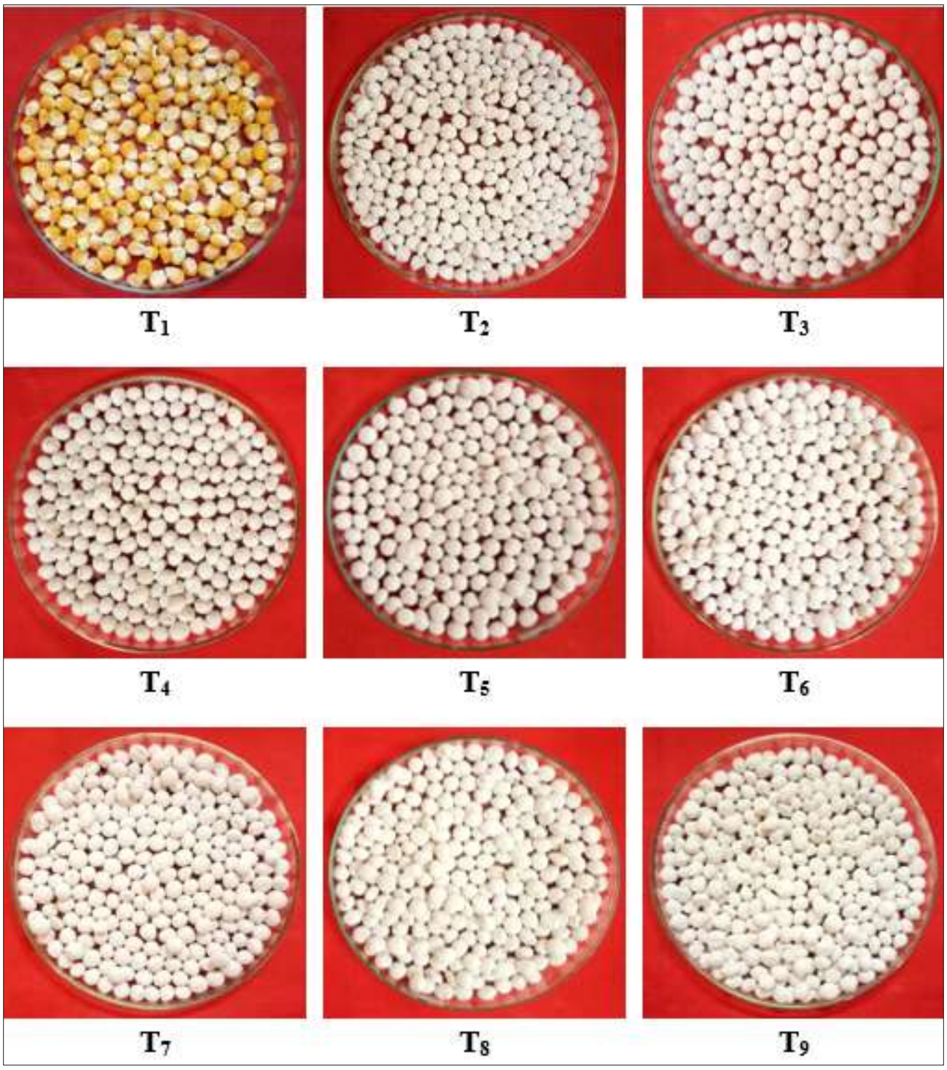

Plate 1: Pelleted seeds of maize hybrid Hema used for sowing

The pelleted seeds (Plate 1) as per the treatment were sown on 14th December, 2019 with recommended spacing of 60 cm between rows and 30 cm between seeds at proper depth of 3 cm. At the time of land preparation full dose of phosphorus and potassium and half dose of nitrogen was applied as basal dose while remaining nitrogen was applied in two equal split applications at knee high stage and pre-tasseling stage. The source of N, P and K were Urea, Diammonium phosphate and Muriate of potash respectively. All the cultural operations were performed as per the package of practices of maize.
The data were recorded from five randomly selected plants which were tagged from each plot and the average for every parameter was worked out. The effect of seed pelleting on initial seed quality parameters, growth parameters and yield attributes were recorded and benefit-cost ratio was calculated

Statistical Analysis
The experimental data thus obtained during the course of investigation were subjected to statistical analysis by applying the Fisher's method of Analysis of Variance technique (ANOVA) to test the significance of overall differences among the treatments (Gomez and Gomez, 1984) [7].

Result and Discussions
Initial seed quality parameters
The data on initial seed quality parameters *viz.*, seed germination%, speed of emergence, SVI-I, SVI-II, seed mycoflora, filed emergence (%) are presented in Table 2. Significant difference was recorded among the treatments. Highest seed germination percentage (92%) (Plate 2), speed of emergence (64.06) and field emergence (92.33%) were recorded in T_1 (control) compared to pelleted seeds. This is possibly due to the performance of pelleting seeds which is influenced by the seed coating material. Because of this coating material seeds take more time to absorb water which is required for the germination. However, the germination percentage of pelleted seeds improved when the pellets were broken (Taylor and Eckenrode, 1993) [19] but took long time for germination when it's with pelleted material.
The highest SVI-1 (3501) and SVI-II (6316) were recorded in T_9 while the lower value was recoded in T_4 (2555) and T_2 (3672) respectively. This is due to increased food reserve mobilization efficiency of pelleted seeds resulted in better seed germination and also seedling length which intern increased the seedling vigour index-I and II in T_9. As zinc is the main component of several dehydrogenase enzymes, which probably activates the seed germination and also seedling growth. The presence of weedicide atrazine in the absence of biofertilizer in the treatment T_2 and the absence of zinc in T_4 results in lower seedling vigour index (Jeyabal and Kuppuswamy, 1999) [8].
The lowest value of seed mycoflora (Plate 3) was recorded in T_5 (2.00%) and the highest was recorded in T_1 (5.00%). This might be due to the presence of fungicide metalaxyl in T_5 and the antagonistic nature of bio agents helps in low disease incidence compared to unpelleted seeds (Wayne, 2003) [20].

Table 2: Effect of seed pelleting on initial seed quality of maize

Treatments	Seed germination	Speed of emergence	SVI-I	SVI-II	Seed mycoflora	Field emergence
T_1	92	64.06	92	64.06	5.00	92.33
T_2	80	56.71	80	56.71	3.00	86.67
T_3	88	55.27	88	55.27	3.33	88.67
T_4	90	43.78	90	43.78	2.67	87.67
T_5	91	57.28	91	57.28	2.00	91.67
T_6	86	48.97	86	48.97	2.33	89.00
T_7	87	45.90	87	45.90	5.00	88.67
T_8	84	51.24	84	51.24	3.00	89.67
T_9	83	51.16	83	51.16	4.67	90.33
Mean	86.78	52.71	86.78	52.71	3.44	89.41
S.Em±	2.60	2.78	2.60	2.78	0.23	0.59
CD (P=0.05)	7.54	8.11	7.54	8.11	0.68	1.61
CV (%)	4.23	10.54	4.23	10.54	11.35	1.04

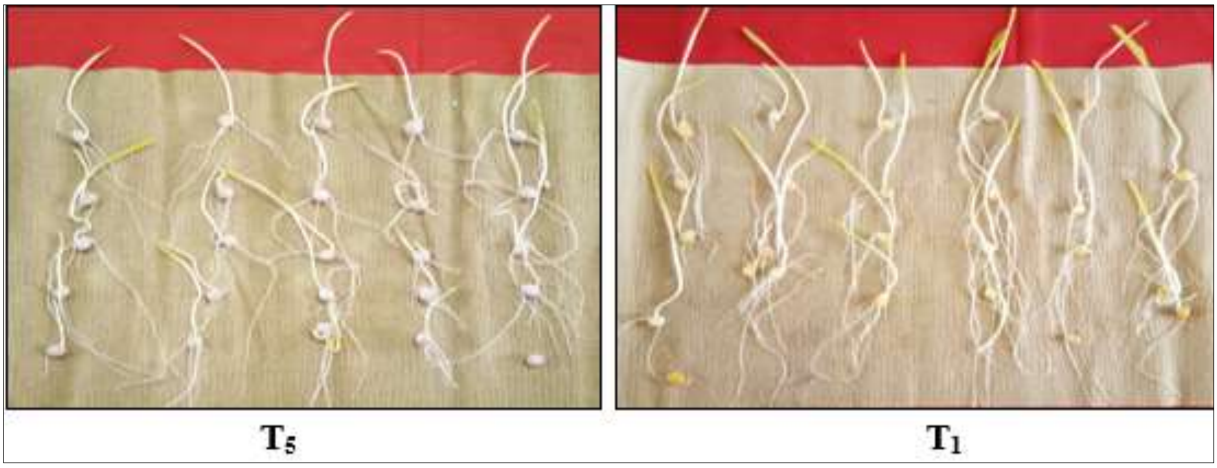

Plate 2: Seed germination of pelleted seeds (T_5) Vs. control (T_1)

Plate 3: Seed mycoflora of pelleted seeds (T_5) Vs. control (T_1)

Growth parameters

The data related to growth parameters *viz.*, plant height, number of leaves per plant, days to 50% silking and tasseling, weed and insect infestation are presented in Table 3. Significant difference was recorded among the treatments with respect to maximum plant height 132.31 cm at 60 DAS and 211.41 cm at harvest and maximum number of leaves 11.53 at 60 DAS and 13.73 at harvest was recorded in the treatment having T_5 compared to T_2 where was found minimum plant height 120.67 cm at 60 DAS and 198.75 cm at harvest and also found minimum number of leaves 8.73 at 60 DAS and 10.60 at harvest. The higher plant height and leaf number could be attributed to the superior root and shoot growth in plants which helped the plants to take up water and nutrients more efficiently and consequently to grow more luxuriantly along with early and uniform emergence of vigorous seedlings. Early supplementations of micro and macro nutrients are provided by the pelleting material at initial establishment of plants (Sujatha and Ambika, 2018) [17]. The significantly minimum number of days 54.93 to 50% tasseling and minimum number of days 58.07 to 50% silking was recorded in the treatment having T_5 respectively. It might be due to seeds treated with bio fertilizers either single or with inorganic fertilizers (Nitrogen and Phosphorous) and micronutrients (zinc) triggers the synthesis of hormones involved in different physiological and biochemical processes of the plants (Dinesh and Eugenia, 2018) [6]. Similar results were also reported by Masuthi (2005) [11] in cowpea and Balaji (1990) [5] and Supreeta Angadi (2004) [18] in soybean when seeds pelleted with zinc sulphate.

Significantly minimum weed infestation was recorded in T_4 (5.57%) at 15 DAS compared to control (9.84%) because of the presence of weedicide in the treatment which suppress the weeds around spermosphere (Zone surrounding seed) in maize (Sahar *et al*., 2011) [13] and minimum insect infestation (Plate 4) was recorded in T_7 (2.40%) at harvest compared to control (6.95%) This is possibly due to the pelleting of seeds with insecticide Fortenza duo (Cyantraniliprole + Thiamethoxam).

Table 3: Effect of seed pelleting on growth parameters of maize

Treatments	Plant height		No. of leaves/plant		50% tasseling	50% silking	Weed infestation	Insect infestation
	60 DAS	At harvest	60 DAS	At harvest			15 DAS	At harvest
T_1	123.92	204.77	9.47	11.80	57.73	62.93	9.84	6.95
T_2	119.19	196.80	8.87	10.60	59.27	64.87	7.41	4.75
T_3	125.25	205.32	10.87	12.40	56.93	58.87	9.53	2.59
T_4	120.67	198.75	9.27	11.00	58.80	64.37	5.57	3.67
T_5	132.31	211.41	11.93	13.73	54.93	58.07	5.93	3.29
T_6	126.35	207.73	10.87	12.53	56.93	60.20	7.22	6.77
T_7	127.12	207.43	10.87	12.00	56.93	59.77	6.43	2.40
T_8	126.97	206.87	11.40	12.47	56.53	60.20	6.30	2.70
T_9	129.33	210.10	11.53	13.07	55.77	59.73	6.50	5.68
Mean	125.68	205.47	10.56	12.18	57.09	61.00	7.19	4.31
S.Em±	2.30	2.90	0.28	0.30	0.83	1.43	0.52	0.22
CD (P=0.05)	6.91	8.70	0.83	0.89	2.49	4.28	1.42	0.65
CV (%)	3.18	2.45	4.53	4.20	2.52	4.05	6.81	8.74

Plate 4: Insect infestation at 30 DAS of pelleted seeds (T_5) Vs. control (T_1)

Yield attributes

The data related to yield attributes *viz.*, cob length, number of cobs per plant, 100 seed weight, cob dry weight, seed yield per hectare and BC ratio are presented in Table 4. The significant difference among the pelleting treatments was observed with respect to cob length. Higher cob length was recorded in T_5 (19.86 cm) and lowest was in T_2 (17.79 cm). It is possibly due to the fact that bio-fertilizers produced the growth promoting substance and acids like acetic, formic, proponic, lactic, glyconic, fumaric and succinic which were positively affected the growth, flowering and yield (Dinesh and Eugenia, 2018) [6].

Maximum number of cobs/plant (1.53) was recorded in T_5 while minimum number of cob (1.00) was found in treatment T_2. The increase in number of cobs per plant possibly due to increase in assimilation of required nutrients and increase in the movement of organic compounds from source to sink due to seed pelleting with $ZnSO_4$ and biofertilizer (Sowmiyabhanu *et al.*, 2016) [16].

The significant difference among the pelleting treatments was observed with respect to 100 seed weight. Highest 100 seed weight was noticed in T_5 (35.97 g) and the lowest weight was recorded in T_2 (32.50 g). This could be due to increase in assimilation of required nutrients and increase in the movement of organic compounds from source to sink due to seed pelleting with $ZnSO_4$ and biofertilizer (Sowmiyabhanu *et al.*, 2016) [16].

Highest cob dry weight was noticed in T_5 (317.53 g) and the lowest weight was recorded in T_2 (239.07 g). This may be due to the cumulative effect of better germination, growth, establishment, leaf area, assimilation of nutrients and better source to sink relationship (Masuthi, 2005) [11].

There was a significant difference noticed in seed yield per hectare among the different pelleting treatments. The maximum yield was detected in T_5 (107.59 q) and was lower in T_2 (66.77 q). It could be due to the fact that combined application of bio fertilizer with atrazine reduced weed density in spermosphere (Zone surrounding seed), which increased yield parameters *viz.*, plant height, dry matter yields, leaf, stem, ear percentages and seed yield in maize (Sahar *et al.*, 2011) [13].

Among different treatments, the highest B: C ratio (2.69) was recorded in T_5 followed by T_9 (2.41) and lowest (1.66) in T_2. This is due to the positive effect of seed pelleting on seed yield attributes resulted in higher seed yield (Ashish *et al.*, 2018) [4].

Table 4: Effect of seed pelleting on yield attributes of maize

Treatments	Cob length (cm)	No. of cobs/plant	100 seed weight (g)	Cob dry weight (g/plant)	Seed yield per hectare (q)	B: C ratio
T_1	18.28	1.20	33.96	263.40	72.35	2.28
T_2	17.79	1.00	32.51	239.07	66.77	1.66
T_3	18.77	1.33	34.28	266.87	83.74	2.10
T_4	18.31	1.00	33.02	245.47	71.48	1.79
T_5	19.86	1.53	35.97	317.53	107.59	2.69
T_6	18.58	1.33	34.58	274.67	93.74	2.38
T_7	18.42	1.20	34.71	263.87	88.67	2.22
T_8	18.68	1.27	34.78	273.13	83.29	2.08
T_9	18.82	1.40	35.44	296.93	94.92	2.41
Mean	18.61	1.25	34.36	271.22	84.73	-
S.Em±	0.35	0.07	0.50	8.31	3.29	-
CD (P=0.05)	1.04	0.21	1.50	24.92	9.86	-
CV (%)	3.24	9.54	2.53	5.31	6.72	-

Conclusion

It can be concluded from the present investigation that, seed pelleting enhanced the germination, seedling establishment, crop performance, seed yield, seed quality and net returns and reduced the weed and insect infestation in maize. The magnitude of seed quality enhancement was higher in seeds pelleted with Polymer @ 4.0 ml kg^{-1} + Metalaxyl @ 3.0 g kg^{-1} + (Cyantraniliprole+ Thiamethoxam) @ 4.0 ml kg^{-1} + Zinc @

2.0 g kg^{-1} + Atrazine @ 10 g kg^{-1}+ *Azotobacter chroococcum* @ 2 g kg^{-1} seeds (T_5) with higher cost benefit ratio (1: 2.28). This seed enhancing pelleting treatment could be used in maize seeds to enhance crop performance and seed yield.

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