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Studies on polymer seed coating with nutrients and pesticides on growth and yield of radish (*Raphanus sativus* L.)

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Abstract

The present investigation entitled "Studies on Polymer Seed Coating with Nutrients and Pesticides on Growth and Yield of Radish (*Raphanus sativus* L.)" was carried out using cv. Pusa Himani. The experiment was laid out in Randomized Complete Block Design (RCBD) with 15 treatments comprising of different combinations of polymer with nutrients and pesticides, in the Research Farm of Department of Vegetable Science for two years (2016 and 2017). The observations in field were recorded on field emergence (%), days to marketable maturity, number of leaves per plant, top length (cm), leaf length (cm), leaf width (cm), root length (cm), root diameter (mm), gross root weight (g), net root weight (g), root/ top ratio: length basis & weight basis and root yield per plot (kg) and per hectare (q). Analysis of variance showed significant differences among the treatment combinations for all the characters studied. Experimental results revealed that polymer seed coating @10 ml+ NPK (19:19:19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed was found superior over all treatments in terms of most of the growth and yield characteristics in both years i.e. 2016 and 2017. Therefore, coating the seeds of radish with polymer @10 ml+ NPK (19:19:19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed can be recommended for getting higher yield of radish in Himachal Pradesh after multilocational testing.

Keywords: Polymer seed coating, nutrients, insecticides, growth and yield, radish

Introduction

Radish (*Raphanus sativus* L.) is the one of the most important root crops belonging to the family Cruciferae. It is grown both in tropical and temperate regions of the world and is probably a native of Europe and Asia. In India, radish is cultivated over an area of 2,03,000 hectares producing 28,98,000 tonnes of roots annually (NHB, 2016) [8]. In hills of Himachal Pradesh, radish is grown during summer months. Seed is a basic and vital input for sustained growth in agricultural productivity and production. Being a biological entity, seed undergoes natural ageing/ deterioration immediately after harvest and the extent of seed deterioration determines the plant stand of the subsequent crop (Kanwar *et al.*, 2010) [6]. Hence, it is imperative to have more farmer friendly strategies for ensuring minimum loss of seed quality during storage. Polymer seed coating or film coating is such an emerging technology. Film coating technology is a sophisticated process of applying precise amount of active ingredients along with a liquid material directly on to the seed surface without obscuring its shape and total seed weight may increase up to 1 to 2 per cent (John *et al*., 2005) [5]. Seed coating also involves the sticking of target materials onto the surface of seeds (Stendahl, 2005) [11]. The polymer coating with negligible thickness of seed coat provides protection from the stress imposed by accelerated ageing, which includes fungal invasion. The coat is thin (8 µm), simple to apply, diffuses rapidly and non-toxic to the seedling during germination. Polymer seed coating along with chemicals improves the emergence of seeds and helps in accurate application of the chemicals, reducing chemical's wastage and helps to make room for including all required ingredients, protectants, nutrients etc. (Chandravathi, 2008) [1]. It also makes sowing operation easier due to the smooth flow of seeds. Addition of colourants helps in visual monitoring of placement accuracy and also enhances the appearance, marketability and consumer preference of seeds.

Materials and Methods

The present investigation entitled "Studies on Polymer Seed Coating with Nutrients and Pesticides on Growth and Yield of Radish (*Raphanus sativus* L.)" was carried out in the Research Farm of Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP), in two experiments during 2016 and 2017. The Vegetable Research Farm is located in the mid-hill zone of Himachal Pradesh, at an altitude of 1273 metres above mean sea level, lying between latitude of 30.5°N and longitude of 77.8°E. Climate of the area is generally sub-temperate and semi-humid characterized by cold winters. The mean annual rainfall is 1000-1300mm, most of which is received from June to September. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The cultivar 'Pusa Himani' was used in the study. The experiment was carried with 15 different combinations of polymer with nutrients and pesticides (Table 1). Sowing of the seeds was done on 10th October, 2016 and 7th October, 2017 at 30cm X 7.5cm spacing in plot size of 2.25m^2 and 100 plants were kept per bed. All the cultural practices to raise the healthy crop of radish were followed as per Package of Practices of Vegetable Crops (Anonymous, 2014) [14]. The observations were recorded on field emergence (%), days to marketable maturity, number of leaves per plant, top length (cm), leaf length (cm), leaf width (cm), root length (cm), root diameter (mm), gross root weight (g), net root weight (g), root/ top ratio: length basis & weight basis, root yield per plot (kg) and per hectare (q) and incidence of diseases, if any, on ten randomly selected plants from each replication. Data on different parameters were analyzed statistically as suggested by Gomez and Gomez (1984) [3].

Table 1: Detail of treatments

T_1	Control (No treatment)
T_2	Polymer seed coating @10 ml/kg seed
T_3	Polymer seed coating @10 ml+NPK (19: 19: 19) @ 5g/kg seed
T_4	Polymer seed coating @10 ml+Potassium dihydro orthophosphate (KH_2PO_4) @ 300mg/kg seed
T_5	Polymer seed coating @ 10 ml+Zinc sulphate ($ZnSO_4$) @ 300mg/kg seed
T_6	Polymer seed coating @ 10 ml+Magnesium sulphate ($MgSO_4$) @ 300mg/ kg seed
T_7	Polymer seed coating @ 10 ml+Carbendazim @ 2g/kg seed
T_8	Polymer seed coating @ 10 ml+Imidacloprid @ 3ml/kg seed
T_9	Polymer seed coating @ 10 ml+Carbendazim @ 2g +Imidacloprid @ 3ml/ kg seed
T_{10}	Polymer seed coating @10 ml+NPK (19: 19: 19) @ 5g+Potassium dihydro orthophosphate (KH_2PO_4) @ 300mg/kg seed
T_{11}	Polymer seed coating @ 10 ml+NPK (19: 19: 19) @ 5g+Zinc sulphate ($ZnSO_4$) @ 300mg/kg seed
T_{12}	Polymer seed coating @10 ml+NPK (19: 19: 19) @ 5g+Magnesium sulphate ($MgSO_4$) @ 300mg/kg seed
T_{13}	Polymer seed coating @ 10 ml+NPK (19: 19: 19) @ 5g+Carbendazim @ 2g/kg seed
T_{14}	Polymer seed coating @10 ml+NPK (19: 19: 19) @ 5g+Imidacloprid @ 3ml/kg seed
T_{15}	Polymer seed coating @10 ml+NPK (19: 19: 19) @ 5g+Carbendazim @ 2g+ Imidacloprid @ 3ml/kg seed

Results and Discussion

Uniform and rapid seedling establishment is desirable, as non- uniform crop emergence results in plants of variable size and competitive ability. Subsequently management practices shall also be less effective on fields with staggered emergence. If stand establishment is poor, yields and quality of the harvested crop will be poor. The ability of polymer seed coating to withstand storage, produce healthy seedlings in a variety of seed beds and soil types, and interact with crop protection agents is critically important. Similarly, addition of pesticides and nutrients in polymer seed coating gives initial protection and faster growth to the emerging seedling.

The field emergence is considered to be an important parameter for assessing the potentiality of seeds to perform better under field conditions. Crop yield and resource use efficiency depends on successful plant establishment in the field. Data pertaining to field emergence has been presented in Table 2. The mean performance of treatments for two years showed that field emergence was significantly higher (84.17 %) in T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, and was statistically at par with T_{13}. However, minimum field emergence (68.22 %) was recorded in T_1 i.e. untreated control. Better maintenance of seed vigour in the coated seeds has subsequently resulted in higher seedling emergence, as compared to the uncoated seeds. Use of pesticides in polymer seed coating in T_{15} also resulted in better emergence. Moreover, the occurrence of abnormal seedlings in film coated seeds was eliminated due to higher and more efficient water consumption. These results are in accordance with the findings of Kosters (1994) [7] in pea, who reported increased field emergence after coating the seeds with polymer along with fungicides and pesticides.

Early maturity is desirable which fetches good returns to the growers. Mean of two years (Table 2) showed that minimum days to marketable maturity (45.67) were taken by T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed and T_9 (polymer seed coating @ 10 ml+ carbendazim @ 2g+ imidacloprid @ 3ml/ kg seed and both these treatments were at par with T_3, T_6, T_{13}, T_2, T_8, T_{12} and T_{11}. Maximum days to marketable maturity (52.00) were taken by T_1 i.e. untreated control. Early plant growth enhancement was reported by Jetiyanon *et al*. (2008) [4], after coating the seeds with polymer along with bacterial spores. Early maturity in treatments T_{15} and T_9 can be attributed to early emergence of seedling and faster growth of the plant as in these treatments nutrients and pesticides have been coated which gave initial boost to the growth of radish plants.

Number of leaves per plant determines the light interception capacity of a crop and is an important indicator of health of a plant, as higher is the number of leaves per plant, higher is the rate of photosynthetic assimilation. It is evident from the mean data presented in Table 2, that maximum number of leaves per plant (16.27) was recorded in T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was statistically at par with T_2, T_{13}, T_5, T_9, T_3 and T_{14}. Minimum number of leaves per plant (13.83) was recorded with T_7 i.e. polymer seed coating @ 10 ml+ carbendazim @ 2g/kg seed. Number of leaves per plant was higher in coated seeds than uncoated control. This may be due to the reason that the hydrophillic nature of polymer leads to activation of cells and results in enhancement of mitochondrial activity leading to the formation of more high energy compounds and vital molecules and these were made available during the early phases of germination which resulted in production of more leaves per plant. Also, readily availability of nutrients and pesticides in T_{15} also gave initial growth to the plant resulting in more number of leaves per plant. Zhang *et al*. (2007) [13] reported better growth parameters after coating the seeds of tomato with polymer and paclobutrazol.

Top length is an important character exhibiting direct relationship with root yield and was directly influenced by incorporating nutrients and pesticides in polymer seed coating in the present study. Among various treatments, highest top length (32.13 cm) was recorded in T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was significantly higher than all other treatments, as is evident by the mean data of both the years. Minimum top length (26.99 cm) was recorded in T_1 i.e. untreated control (Table 2). The increased top length in polymer coated seeds with nutrients and pesticides (T_{15}) may be due to early emergence and also rapid cell division and elongation in meristematic region. The higher top length may also be attributed due to initial activation of metabolic activity of seed. More number of leaves per plant in T_{15} also resulted in more photosynthetic area resulting in more growth of the plant leading to higher top length.

Studies on the effect of the polymer seed coating have shown that they can influence positively the assimilating apparatus-leaf area, fulfilling the leading role in photosynthesis. It is apparent from the mean data (Table 2), that there were significant differences among various treatments for leaf length. Highest leaf length (26.65 cm) was recorded in T_6 i.e. polymer seed coating @ 10 ml+ magnesium sulphate ($MgSO_4$) @ 300mg/ kg seed, which was statistically at par with T_{13}, T_{15}, T_3, T_5, T_2, T_8 and T_{12}. However, minimum leaf length (24.57 cm) was recorded in T_1 i.e. untreated control. The plant food is prepared in leaves and then is transported to its other organs. The reason for production of maximum leaf length with polymer coated seeds along with nutrients may be due to the fact of application of precise and sufficient quantities of nutrients (mainly nitrogen) that resulted in increase in vegetative growth as compared to the control. Xiong *et al*. (2005) [12] reported more chlorophyll accumulation and dry matter production in cucumber after coating the seeds with polymer and uniconazole which resulted in higher leaf length.

It is apparent from the mean data (Table 2) that leaf width was significantly affected by various treatments. Leaf width was maximum (6.80 cm) in T_{13} i.e. polymer seed coating @ 10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g/kg seed, which was statistically at par with T_6, T_{12}, T_8, T_{15}, T_{11}, T_5, T_{10}, T_9 and T_3. Minimum leaf width (5.70 cm) was observed in T_1 i.e. untreated control. Radish is a fast-growing vegetable and requires high amount of nutrients for maximum production of healthy leaves. Addition of nutrients in polymer seed coating resulted in higher leaf width. This may be attributed to the addition of NPK (19:19:19), as nitrogen plays a crucial role in cell division, cell enlargement and protein synthesis. Zhang *et al*. (2007) [13] reported that film coating with paclobutrazol in tomato influenced the proline and chlorophyll content of leaves and resulted in higher leaf width.

Table 2: Effect of polymer seed coating with nutrients and pesticides on growth characters in radish

Treatments	Field emergence (%)	Days to marketable maturity	Number of leaves per plant	Top length (cm)	Leaf length (cm)	Leaf width (cm)
	Mean	Mean	Mean	Mean	Mean	Mean
T_1	68.22 (8.32)	52	14.05	26.99	24.57	5.70
T_2	72.13 (8.55)	47.17	15.77	29.83	25.96	6.15
T_3	73.77 (8.65)	46.5	15.07	29.86	26.28	6.17
T_4	79.63 (8.98)	49.5	14.10	29.83	24.77	6.11
T_5	76.93 (8.83)	51.5	15.40	30.69	26.26	6.39
T_6	75.21 (8.73)	46.5	14.90	29.40	26.65	6.74
T_7	77.30 (8.85)	50.83	13.83	28.93	24.53	6.11
T_8	77.53 (8.86)	47.33	14.57	30.64	25.51	6.59
T_9	77.43 (8.85)	45.67	14.60	29.76	24.96	6.22
T_{10}	76.73 (8.81)	49.5	14.60	30.41	24.59	6.29
T_{11}	77.52 (8.86)	48.83	14.44	29.11	24.97	6.49
T_{12}	76.30 (8.79)	48.5	13.90	29.75	25.42	6.74
T_{13}	82.41 (9.13)	46.5	15.50	30.38	26.63	6.80
T_{14}	74.86 (8.71)	49.5	15.07	30.10	25.64	5.90
T_{15}	84.17 (9.23)	45.67	16.27	32.13	26.48	6.56
CD at 5% (T)	0.13	3.42	1.23	1.43	1.4	0.63

*Figures in the parentheses are square root transformed values

Root length and diameter directly affect the weight of root which subsequently affect root yield per unit area. The data pertaining to root length has been depicted in Table 3. Among treatments, maximum root length (18.55 cm) was recorded in T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was statistically at par with T_{12}, T_{13}, T_5, T_3, T_4 and T_6. However, minimum root length (16.04 cm) was recorded in T_1 i.e. untreated control. The application of nutrients plays a significant role in growth and yield parameters of radish. The higher root length might be the result of faster initial growth of the plant due to availability of nutrients and pesticides in the root zone. The results are in accordance with the finding of Xiong *et al*. (2005) [12], who recorded improved root growth in cucumber by polymer coating with uniconazole.

On the basis of observations recorded on root diameter, the mean data of two years has been summarized and depicted in Table3. An examination of the data showed that maximum root diameter (31.53 mm) was recorded with T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was statistically higher than all other treatments. However, minimum root diameter (26.57mm) was recorded with T_1 i.e. untreated control. These results are in conformity with the findings of Dhiman (2015) [2] who reported that fruit diameter was higher in okra after coating with polymer and imidacloprid. This may be due to vigorous growth of the plants due to polymer coating leading to more photosynthesis of assimilates.

Gross root weight is an important parameter which reflects the vigour of the seed. Healthy leaves and roots result into higher gross root weight due to more dry matter production. Data presented in Table 3 indicated that among treatments, highest gross root weight (212.27 g) was recorded in T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was statistically at par with T_3, T_9, T_{10} and T_{12}. Minimum gross root weight (169.70 g) was recorded in T_1 i.e. untreated control. As it is evident from previous discussion that gross root in T_{15} was highest because this treatment produced root with more length and diameter. The top length was also higher in T_{15}. All these factors contributed in more gross root weight in T_{15}.

Net root weight was significantly affected by various treatments and was maximum (160.13 g) in T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was statistically at par with T_3, T_{12}, T_{13}, T_{10} and T_9. Minimum net root weight (116.52 g) was recorded in T_1 i.e. untreated control. Net root weight was 10.6% higher in T_{15} than in T_1. The progressive improvement in quality parameters of radish root with the use of polymer with nutrients and pesticides (T_{15}) might be due to increase in growth parameters, which might have resulted in improved uptake of nutrients and photosynthetic activities and finally more net root weight. More length and diameter of root in T_{15} also contributed to more net root weight. Sharma (2014) [9] reported higher fruit weight in French bean after coating the seeds with polymer along with bavistin and imidacloprid.

Root/top ratio on length basis reflects the proportionate growth of root with respect to leaves on length basis. The data pertaining to root/top ratio on length basis has been depicted in Table 3. Among treatments, highest root/top ratio on length basis (0.61) was recorded in T_{12} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ magnesium sulphate ($MgSO_4$) @ 300mg/kg seed, which was statistically at par with T_1, T_3, T_4, T_6, T_7, T_{13}, T_9, T_{11}, T_5 and T_{15}. Minimum root/top ratio on length basis (0.54) was recorded in T_{14} i.e. polymer seed coating @10 ml+NPK (19: 19: 19) @ 5g+ imidacloprid @ 3ml/kg seed.

Root/top ratio on weight basis shows the proportionate growth of root and leaves on weight basis. Mean data presented in Table 3 indicated that among treatments, highest root/top ratio on weight basis (3.07) was recorded in T_{15} i.e. polymer seed coating @10 ml+NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was statistically at par with T_5, T_{13}, T_1, T_3, T_{11}, T_2 and T_8. Minimum root/top ratio on weight basis (2.32) was recorded in T_{10} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ potassium dihydro orthophosphate (KH_2PO_4) @ 300mg/kg seed.

Root yield per unit area is a major objective in any experimentation. A perusal of the mean data presented in Table 3 revealed that maximum yield per plot (8.28 kg) was recorded in T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was statistically at par with T_{13}, T_{12}, T_8 and T_{11}. Minimum root yield per plot (6.20 kg) was observed in T_1 i.e. untreated control. It is well understood that yield is a parameter which is highly and positively affected by length, diameter, net root weight, gross root weight and total number of survived plants. All these characters were significantly improved by the polymer seed coating with nutrients and pesticides (T_{15}). This increase in root yield may be due to increased vegetative growth and foliage, giving better opportunities for photosynthetic activities and consequently increasing carbohydrates in the root resulting higher yield. The results are in conformity with the findings of Srivastava *et al*. (2011) [10], who reported that polymer coating with carbendazim in tomato, chilli and brinjal led to higher field emergence with less seedling mortality and ultimately resulted in higher yield.

High yield is the basic objective of all seed quality improvement programmes. It is of utmost importance to develop a technology which has the potential to surpass the commercially adopted technologies otherwise it will be of no significance in this context. On the basis of observations recorded on root yield per hectare, the data has been summarized and depicted in Table 3. An examination of the data showed that highest root yield per hectare (294.32q) was recorded in T_{15} i.e. polymer seed coating @10 ml+ NPK (19: 19: 19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed, which was statistically at par with T_{13}, T_{12}, T_8 and T_{11}. Minimum root yield per hectare (220.53 q) was recorded in T_1 i.e. untreated control. Root yield per hectare was 33.45% higher in T_{15} than in T_1 i.e. untreated control. The increase in root yield per hectare in T_{15} may be due to the incorporation of nutrients in polymer seed coating, which enhanced soil fertility near the vicinity of seed, which resulted in healthy crop and ultimately resulted in higher yields. Use of pesticides in polymer coating also helped in better survival of the plants leading to optimum population per unit area. The present results are in accordance with the findings of Dhiman (2015) [2], who observed that coating the seeds of okra with polymer and imidacloprid before storage, helped in getting higher seed and fruit yield per hectare.

Table 3: Mean data of two years for effect of polymer seed coating with nutrients and pesticides on yield characters in radish

Treatments	Root length (cm)	Root diameter (mm)	Gross root weight (g)	Net root weight (g)	Root/top ratio: length basis	Root/top ratio: weight basis	Root yield per plot (kg)	Root yield per hectare(q)
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
T_1	16.04	26.57	169.70	116.52	0.60	2.92	6.20	220.53
T_2	16.90	28.18	186.81	137.24	0.57	2.84	6.44	228.96
T_3	17.77	28.42	207.47	154.34	0.60	2.90	7.03	249.81
T_4	17.74	29.17	184.79	132.12	0.60	2.54	6.63	235.88
T_5	17.79	29.02	194.37	144.67	0.58	3.02	6.45	229.14
T_6	17.73	28.35	182.19	130.72	0.60	2.55	7.07	251.55
T_7	17.35	28.29	197.43	142.05	0.60	2.56	6.48	230.49
T_8	17.46	28.41	194.71	142.76	0.57	2.72	7.72	274.53
T_9	17.40	28.52	203.55	148.42	0.59	2.50	7.01	249.16
T_{10}	17.19	27.81	202.16	149.12	0.57	2.32	7.01	249.19
T_{11}	17.01	29.15	191.28	138.62	0.59	2.89	7.69	273.37
T_{12}	18.14	29.28	201.74	150.33	0.61	2.97	7.90	280.99
T_{13}	18.12	29.00	199.34	150.07	0.60	2.99	7.94	282.42
T_{14}	16.27	27.48	186.11	132.59	0.54	2.54	6.92	246.10
T_{15}	18.55	31.53	212.27	160.13	0.58	3.07	8.28	294.32
CD at 5% (T)	0.85	1.15	12.64	13.27	0.03	0.42	0.65	23.06

In radish, diseases such as *Alternaria* leaf spots and white rust are common but in the present study, no disease incidence was recorded.

From the results as presented and discussed above, it can be concluded that to get higher yield of quality roots in radish, the seeds should be coated before sowing with polymer @10 ml+ NPK (19: 19: 19) @ 5 g+ carbendazim @ 2 g+ imidacloprid @ 3 ml/kg seed.

Conclusion
From the present investigation, it can be concluded that the treatment T_{15} (polymer seed coating @10 ml+NPK (19:19:19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed), was found superior over all treatments in terms of most of the growth and yield characteristics in both the years i.e. 2016 and 2017. Therefore, coating the seeds of radish before sowing with polymer @10 ml+ NPK (19:19:19) @ 5g+ carbendazim @ 2g+ imidacloprid @ 3ml/kg seed can be recommended for getting higher yield of radish in Himachal Pradesh after multilocational testing.

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