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Effect of seed colouring with natural and artificial dyes on storability of paddy seeds

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ABSTRACT

An investigation was undertaken to study the effect of seed colouring with a few natural and artificial dyes on storability of paddy seeds. Freshly harvested paddy seeds were treated with fungicide (Thiram @ 2g per kg seed), followed by colouring with five artificial dyes@ 0.75% concentrations, viz., Aniline blue, Congo red, Methyl violet, Bromocresol purple and Coomasie brilliant blue, and four natural dyes, namely,beet (root tuber extract), turmeric (dried rhizome powder), mehndi (leaf extract), marigold (extract from petals). One control was also taken, in which only fungicide treatment was given. After colouring, the seeds were dried to moisture content below MSCS (13.0%) and stored in cloth bags under ambient conditions for a period of 8 months, i.e. from October 2014 to May 2015. Most of the dye treatments, both artificial and natural, had some deleterious effect on maintenance of viability in seeds, as compared to control, though in some cases the differences were statistically non-significant. None of the dyes had any beneficial effect on germination or vigour parameters. Among the artificial dyes, least deleterious effect was observed in case of seeds treated with Bromocresol purple and Congo red, in terms of various physiological parameters like germinability, percent abnormal seedlings, seed vigour indices and field emergence. Among natural dyes, mehndi and marigold treated seeds gave better results than the beet and turmeric treated seeds, in terms of the physiological parameters. However, seeds coloured with turmeric showed significantly lower insect infestation throughout the period of storage, as compared to the other treatments and control, clearly indicating its role in control of insect infestation during storage. Maximum deleterious effect of seed physiological parameters was recorded in case of Aniline blue and Methyl violet.

Key words: *Seed colouring, seed quality, seed storability, paddy seed*

Among various seed enhancement techniques, seed colouring, or the practice of providing an exogenous colour coating to seeds, started as a necessary practice in America and some European countries to avoid the possibility of inadvertent use of treated seeds as food or feed. Colouring of seed has several advantages like, improving seed marketability, improving the appearance of a lot in case of seed discolouration, enabling brand identification, acting as a visual means of ensuring uniformity of seed treatment, enabling farmers for easy identification of varieties based on colour, acting as insect and bird repellent, and checking adulteration by giving different colours to different batches of seeds. In India, seed colouring is only of relatively recent interest and is still considered by many as of lesser importance than the other enhancement techniques or even extravagant.

Colouring of seeds is done by use of artificial dyes or natural colouring pigments. Some of the natural pigments and artificial dyes available in the market may have deleterious effect on seed storability and its subsequent performance. A few workers have studied the effect of dyes on the seed quality. The effect of seed colouring on the quality of soybean and tomato seeds was studied by Tonapi *et al.*(2006a) encompassing 25 dyes at 0.75% concentration and concluded that the dyes Rhodamine-B, Fast green and Malachite green were the best dyes for soybean seed.

For tomato seeds, Rhodamine-B and Fast green were found to have least deleterious effect on the seed quality. From a similar experiment, Tonapi *et al.*(2006b) reported that the dyes Rhodamine-B, Fast green and Fuchsine, in order of preference, were found to be the best among all dyes in having minimum deleterious effect on both paddy and maize seeds. Similarly, the dyes Rhodamine-B and Erichroblack-T in castor, Rhodamine-B and Cotton blue in sunflower and Rhodamine-B, Fuchsine and Neutral Red in safflower had the least deleterious effect on seed quality during storage and its subsequent performance (Tonapi *et al*. 2006c). HarinathBabu *et al.*(2007) reported that the dyes, Rhodamine-B, Fuchsine and Titan yellow for red gram, Rhodamine-B, Fuchsine and Phenol red for black gram an Rhodamine-B, Crystal violet and Titan yellow for Bengal gram were found to be the best dyes for seed colouring at 0.75% concentration. Colouring of seeds with green herbal textile dye + insecticide treatment has been reported to control rice weevil infestation in hybrid sorghum (Navi *et al*. 2006). Though the above-mentionedstudies have thrown light on the effectiveness of seed colouring on the storability and performance of seeds, further research needs to be undertaken to substantiate the above results encompassing more number of crops and by using more number of natural or artificial dyes. Considering the above discussions, the present study was undertaken to study the effect of seed colouring on the physiological properties in paddy seeds and identify various dye(s) suitable for colouring of paddy seeds vis à vis seed storability.

MATERIALS AND METHODS

Freshly harvested paddy seeds were treated with fungicide (Thiram @ 2g per kg seed), followed by colouring with five artificial dyes @ 0.75% concentration, *viz*., Aniline blue (T_1), Congo red (T_2), Methyl violet (T_3), Bromocresol purple (T_4) and Coomasie brilliant blue (T_5), and four natural dyes, *viz*., beet (root tuber extract) (T_6), turmeric (dried rhizome powder) (T_7), mehndi (leaf extract) (T_8), marigold (extract from petals) (T_9). One control (T_{10}) was also taken, in which only fungicide treatment was given. After colouring, the seeds were dried to moisture contents below minimum seed certification standards for paddy (13.0%) and stored in cloth bags under ambient conditions for a period of 8 months, *i.e.,* from October 2014 to May 2015. The experiment was laid out in completely randomised design with three replications. Observations on seed moisture content (%), germination (%), seed vigour index-I, speed of germination, infected seeds (%), insect infestation (%), germination after accelerated ageing (%) and field emergence (%) were recorded at monthly intervals. The data obtained from the experiment were analysed using suitable statistical techniques (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Seed colouring with artificial and natural dyes had little effect on the seed moisture content during storage. The variation among the treatments and in comparison to control was found to be statistically non-significant (Table 1). However, the mean seed moisture content (during 8 months) was highest in T_7 (turmeric) (12.11%) and lowest in T_1 and T_3 (11.72%), though the difference among the treatments was found to be non-significant. The percent change in moisture content over initial value ranged from 4.30% in case of T_2 (Congo red) to13.13% in case of T_8(marigold).

Seed germination among all the treatments decreased gradually with the increase in storage period. The mean germination potential of T_{10} (control) (90.03%), *i.e.*, seed treated with fungicide only and without any colouring, was highestduring 8 months of storage (Table 2), while all the dye treatments had a slight deleterious effect on seed germinability. Among the artificial dyes, T_4 (Bromocresol purple), T_2 (Congo red) and T_5 (Coomasie brilliant blue) proved to have least deleterious effect on germination potential of the seeds. Maximum deleterious effect was observed in case of T_3 (Methyl violet) (85.50% mean of 8 months) and T_1 (Aniline blue) (85.88% mean of 8 months). The percent decrease in germinability over initial value ranged from 4.88% in case of T_{10} (control) to 15.41% in case of T_1 (Aniline blue).

In comparison to all the dye treatments, T_{10} (control) recorded the highest Seed Vigour Index-I values, followed by T_5 (Coomasie brilliant blue) (Table3). Low SVI-I values were recorded in case of T_3 (Methyl violet) and T_1 (Aniline blue). The two treatments also recorded the highest percent decrease

Table 1. Changes in moisture content (%) of paddy seeds during 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Moisture content (%)								
	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Mean
T_1 :Aniline blue	11.52	11.52	11.52	11.52	11.52	11.52	11.52	11.52	11.72
T_2 : Congo red	11.85	11.85	11.85	11.85	11.85	11.85	11.85	11.85	11.93
T_3 : Methyl violet	11.23	11.23	11.23	11.23	11.23	11.23	11.23	11.23	11.72
T_4 :Bromocresol purple	12.01	12.01	12.01	12.01	12.01	12.01	12.01	12.01	11.94
T_5 :Coomasie brilliant blue	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.97
T_6 : Beet (Beta vulgaris)	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.91
T_7 : Turmeric (*Curcuma longa*)	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	12.11
T_8 : Mehndi (*Lawosni ainermis*)	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.85
T_9 : Marigold (*Tagetes erecta*)	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.89
T_{10} : control	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.31	11.89
S.E.M (±)	0.385	0.461	0.331	0.419	0.524	0.486	0.544	0.379	
C.D.0.05	NS	NS	NS	NS	NS	NS	NS	NS	
CV%	1.53	1.84	2.56	2.93	3.01	1.82	2.96	2.53	

Table 2. Changes in germination (%) of paddy seeds during 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Germination (%)								
	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Mean
T_1 :Aniline blue	92.50 (9.62)*	92.00 (9.59)*	89.75 (9.47)*	86.00 (9.27)*	85.25 (9.23)*	82.25 (9.07)*	81.00 (9.00)*	78.25 (8.85)*	85.88
T_2 : Congo red	91.50 (9.57)*	91.25 (9.55)*	90.00 (9.49)*	88.25 (9.39)*	87.50 (9.35)*	87.00 (9.33)*	86.75 (9.31)*	86.2 (9.29)*	88.56
T_3 : Methyl violet	91.75 (9.58)*	90.00 (9.49)*	88.75 (9.42)*	86.00 (9.27)*	85.50 (9.25)*	82.75 (9.10)*	81.25 (9.01)*	78.00 (8.83)*	85.50
T_4 :Bromocresol purple	92.00 (9.59)*	91.50 (9.57)*	90.75 (9.53)*	88.00 (9.38)*	87.75 (9.37)*	87.50 (9.35)*	87.00 (9.33)*	86.50 (9.30)*	88.88
T_5 :Coomasie brilliant blue	92.25 (9.60)*	91.75 (9.58)*	90.75 (9.53)*	88.50 (9.41)*	87.00 (9.33)*	86.75 (9.31)*	85.75 (9.26)*	84.00 (9.17)*	88.34
T_6 : Beet (*Beta vulgaris*)	92.25 (9.60)*	91.75 (9.58)*	91.25 (9.55)*	89.25 (9.45)*	87.75 (9.37)*	86.50 (9.30)*	84.25 (9.18)*	80.00 (8.94)*	87.88
T_7 : Turmeric (*Curcuma longa*)	91.25 (9.55)*	91.00 (9.54)*	89.75 (9.47)*	88.75 (9.42)*	86.50 (9.30)*	86.00 (9.27)*	84.25 (9.18)*	80.75 (8.99)*	87.28
T_8 : Mehndi (*Lawosni ainermis*)	92.50 (9.62)*	91.75 (9.58)*	91.50 (9.57)*	90.00 (9.49)*	87.25 (9.34)*	86.50 (9.30)*	84.50 (9.19)*	81.50 (9.03)*	88.19
T_9 : Marigold (*Tagetes erecta*)	91.75 (9.58)*	91.50 (9.57)*	90.25 (9.50)*	89.50 (9.46)*	88.75 (9.42)*	87.75 (9.37)*	86.50 (9.30)*	85.25 (9.23)*	88.91
T_{10} : control	92.25 (9.60)*	92.00 (9.59)*	91.50 (9.57)*	90.50 (9.51)*	89.50 (9.46)*	88.75 (9.42)*	88.00 (9.38)*	87.75 (9.37)*	90.03
S.E.M (±)	0.103	0.142	0.138	0.073	0.063	0.146	0.093	0.140	
$C.D._{0.05}$	NS	NS	NS	0.216	0.187	0.431	0.275	0.414	
CV%	2.33	1.89	2.52	2.79	2.16	3.22	2.94	2.86	

*Figures in the parentheses are square root transformed values (y= $\sqrt{x}$)

in SVI-I values during 8 months of storage, thus suggesting some deleterious effect of the two treatments of seed viability maintenance during storage. The highest mean SVI-I (during 8 months) of 2771.41 was recorded in case of T_{10} (control), while the value was lowest (2026.22) in case of T_3 (Methyl violet). Other treatments showing higher SVI-I values were T_2 (Congo red), T_4 (Bromocresol purple) and T_9 (marigold).

With regards to speed of germination, best result was recorded in case of T_6 (beet) (mean value of 17.67%), followed by T_4 (Bromocresol purple) (16.31%),T_7 (turmeric) (16.29%) and T_9 (marigold) (16.25%) (Table 4). Lowest speed of germination value was recorded in case of T_5 (Coomasie brilliant blue) (12.97%).

In comparison to the dye treatments, highest

Table 3. Changes in Seed Vigour Index-I of paddy seeds during 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Seed Vigour Index-I								
	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Mean
T_1 :Aniline blue	2374.9	2338.5	2235.7	2099.4	2018.7	1908.7	1860.9	1761.7	2074.80
T_2 : Congo red	2915.6	2849.5	2782.4	2673.7	2571.5	2505.6	2473.5	2410.0	2647.73
T_3 : Methyl violet	2312.1	2245.3	2169.9	2050.6	1997.9	1895.0	1823.4	1715.5	2026.22
T_4 :Bromocresol purple	2857.5	2785.2	2679.5	2546.3	2488.3	2431.6	2369.3	2308.6	2558.27
T_5 :Coomasie brilliant blue	2779.0	2708.7	2652.4	2509.0	2417.2	2362.0	2288.1	2196.6	2489.12
T_6 : Beet (*Beta vulgaris*)	2558.1	2493.3	2430.2	2317.8	2210.5	2146.0	2048.3	1906.1	2263.79
T_7 : Turmeric (*Curcuma longa*)	2535.8	2478.3	2395.4	2321.3	2217.2	2138.3	2052.9	1928.2	2258.43
T_8 : Mehndi (*Lawosni ainermis*)	2313.4	2271.7	2220.2	2140.1	2033.3	1975.5	1871.9	1769.3	2074.43
T_9 : Marigold (*Tagetes erecta*)	2790.6	2739.9	2648.4	2573.9	2489.7	2412.4	2330.5	2250.8	2529.51
T_{10} : control	3034.1	2965.4	2919.8	2830.1	2714.9	2638.3	2563.6	2505.2	2771.41
S.E.M (±)	116.26	145.51	162.09	111.82	109.94	167.16	114.30	149.73	
$C.D._{0.05}$	342.98	429.24	478.17	329.86	324.32	493.11	337.18	441.70	
CV%	3.25	2.19	2.76	2.27	2.83	3.13	2.20	2.50	

Table 4. Changes in speed of germination of paddy seeds during 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Speed of germination								
	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Mean
T_1 :Aniline blue	16.42	15.93	15.45	15.14	14.69	14.25	13.82	13.40	14.89
T_2 : Congo red	15.93	15.61	15.14	14.99	14.54	14.11	13.68	13.27	14.66
T_3 : Methyl violet	16.67	16.17	15.68	15.21	14.76	14.32	13.89	13.47	15.02
T_4 :Bromocresol purple	18.15	17.42	16.90	16.56	16.07	15.58	15.12	14.66	16.31
T_5 :Coomasie brilliant blue	14.23	14.09	13.67	13.12	12.72	12.34	11.97	11.61	12.97
T_6 : Beet (*Beta vulgaris*)	19.32	18.93	18.37	18.00	17.46	16.93	16.43	15.93	17.67
T_7 : Turmeric (*Curcuma longa*)	18.24	17.51	16.99	16.48	15.98	15.50	15.04	14.59	16.29
T_8 : Mehndi (*Lawosni ainermis*)	16.23	15.74	15.27	15.12	14.66	14.22	13.80	13.38	14.80
T_9 : Marigold (*Tagetes erecta*)	18.20	17.47	16.95	16.44	15.95	15.47	15.00	14.55	16.25
T_{10} : control	15.56	15.40	14.94	14.79	14.35	13.92	13.50	13.10	14.45
S.E.M (±)	1.076	1.011	1.243	1.080	1.161	0.988	1.075	1.195	
$C.D._{0.05}$	3.174	2.983	3.668	3.185	3.424	2.916	3.171	3.526	
CV%	3.22	3.18	3.40	2.97	2.58	2.84	2.26	2.76	

mean germination percentage after accelerated ageing (62.56%) was recorded in case of T_{10} (control), clearly indicating some deleterious effect of the treatments on seed quality during storage (Table 5). Among the treatments, T_4 (Bromocresol purple) and T_9 (marigold) gave good mean germination values after accelerated ageing (62.19% and 62.22%, respectively), while T_1 (Aniline blue) and T_3 (Methyl violet) recorded the least

Table 5. Changes in germination (%) after accelerated ageing of paddy seeds during 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Germination (%) after accelerated ageing								
	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Mean
T_1 :Aniline blue	69.25	67.50	64.25	60.25	58.75	55.00	53.50	50.50	59.88
T_2 : Congo red	69.50	67.50	64.00	62.50	60.75	58.25	57.00	55.25	61.84
T_3 : Methyl violet	69.00	66.00	63.50	60.50	58.25	55.00	54.50	50.25	59.63
T_4 :Bromocresol purple	69.75	67.75	64.25	62.75	60.25	59.75	57.25	55.75	62.19
T_5 :Coomasie brilliant blue	69.25	67.50	64.50	62.25	59.50	58.75	57.00	54.75	61.69
T_6 : Beet (*Beta vulgaris*)	69.25	67.75	65.00	62.75	60.75	58.50	56.75	51.00	61.47
T_7 : Turmeric (*Curcuma longa*)	68.50	66.50	64.75	62.25	59.00	58.00	56.50	52.50	61.00
T_8 : Mehndi (*Lawosni ainermis*)	69.75	67.65	65.50	63.00	59.75	58.25	56.75	52.00	61.58
T_9 : Marigold (*Tagetes erecta*)	69.25	67.50	64.50	63.75	60.75	59.50	57.00	55.50	62.22
T_{10} : control	69.50	67.00	65.75	63.25	61.00	59.25	58.25	56.50	62.56
S.E.M (±)	0.718	0.686	0.724	0.828	0.614	0.924	0.869	1.012	
$C.D._{0.05}$	NS	NS	2.136	2.442	1.811	2.725	2.564	2.984	
CV%	2.56	2.86	1.83	3.22	2.74	2.68	2.59	2.06	

mean germination values after accelerated ageing (59.88% and 59.63%, respectively). The percent reduction in germination after accelerated ageing on completion of storage period over initial value was highest in case of T_1 (Aniline blue) and T_3 (Methyl violet), whereas the value was lowest in case of T_{10} (control).

In comparison to the dye treatments, highest field emergence was recorded in case of T_{10} (control) (mean value of 81.53%), while all the dye treatments showed a slight deleterious effect on the seeds (Table 6). Among the treatments, best results were given by T_9 (marigold) (mean value of 80.53%), followed by T_4 (Bromocresol purple) (80.41%). Lowest field emergence values were observed in case of T_3 (Methyl violet) (77.44%) and T_1 (Aniline blue) (77.72%), clearly indicating maximum deleterious effect of the seeds, giving a similar trend to that of the observations on germination percentage after accelerated ageing. The percent decrease in field emergence values over the initial value ranged from 8.50% in case of T_{10} (control) to 18.24% in case of T_1 (Aniline blue).

The percent infected seeds were found to be higher in T_{10} (control) (mean value of 1.81%) as well as all the natural dyes, as compared to the artificial dyes, clearly indicating that the artificial dyes supplemented the fungicide treatment in controlling the pathogens to a greater extent (Table 7). Lowest percentage of infected seeds was recorded in case of T_1 (Aniline blue) (mean value of 0.44%), followed by T_5 (Coomasie brilliant blue) (mean value of 0.97%), in most of the crop seeds. The treatment T_1 (Aniline blue) showed least percentage of infected seeds during all the months of storage. Other treatments showing low percentage of infected seeds are T4 (Bromocresol purple), T_2 (Congo red) and T_3 (Methyl violet).

Among all the treatments, least insect infestation was recorded in case of T_7 (turmeric) (mean value of 0.09%), followed by T_9 (marigold) (0.22%), whereas it was highest (0.50%) in case of T3 (Methyl violet) (Table 8). The treatment T_7 (turmeric) was found to produce significantly lower percentage of insect infestation throughout the storage period. Among the artificial dyes, T_2 (Congo red) gave better result

Table 6. Changes in field emergence (%) of paddy seeds during 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Field emergence (%)								
	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Mean
T_1 :Aniline blue	85.00 (9.22)*	84.50 (9.19)*	81.75 (9.04)*	78.25 (8.85)*	76.75 (8.76)*	74.00 (8.60)*	72.00 (8.49)*	69.50 (56.48)**	77.72
T_2 : Congo red	84.25 (9.18)*	84.25 (9.18)*	82.00 (9.06)*	80.25 (8.96)*	78.75 (8.87)*	78.25 (8.85)*	77.25 (8.79)*	76.75 (61.17)**	80.22
T_3 : Methyl violet	84.50 (9.19)*	82.75 (9.10)*	80.75 (8.99)*	78.25 (8.85)*	77.00 (8.77)*	74.50 (8.63)*	72.25 (8.50)*	69.50 (56.48)**	77.44
T_4 :Bromocresol purple	84.25 (9.18)*	84.25 (9.18)*	82.50 (9.08)*	80.00 (8.94)*	79.00 (8.89)*	78.75 (8.87)*	77.50 (8.80)*	77.00 (61.34)**	80.41
T_5 :Coomasie brilliant blue	85.00 (9.22)*	84.50 (9.19)*	82.75 (9.10)*	80.50 (8.97)*	78.25 (8.85)*	78.00 (8.83)*	76.25 (8.73)*	74.75 (59.83)**	80.00
T_6 : Beet (*Beta vulgaris*)	85.25 (9.23)*	84.50 (9.19)*	83.00 (9.11)*	81.25 (9.01)*	79.00 (8.89)*	78.00 (8.83)*	75.00 (8.66)*	71.25 (57.58)**	79.66
T_7 : Turmeric (*Curcuma longa*)	84.00 (9.17)*	83.75 (9.15)*	81.75 (9.04)*	80.75 (8.99)*	78.00 (8.83)*	77.50 (8.80)*	75.00 (8.66)*	72.00 (58.05)**	79.09
T_8 : Mehndi (*Lawosni ainermis*)	85.00 (9.22)*	84.50 (9.19)*	83.25 (9.12)*	82.00 (9.06)*	78.50 (8.86)*	78.00 (8.83)*	75.25 (8.67)*	72.50 (58.37)**	79.88
T_9 : Marigold (*Tagetes erecta*)	84.50 (9.19)*	84.25 (9.18)*	82.00 (9.06)*	81.50 (9.03)*	80.00 (8.94)*	79.00 (8.89)*	77.00 (8.77)*	76.00 (60.67)**	80.53
T_{10} : control	85.25 (9.23)*	84.50 (9.19)*	83.25 (9.12)*	82.50 (9.08)*	80.50 (8.97)*	80.00 (8.94)*	78.25 (8.85)*	78.00 (62.03)**	81.53
S.E.M (±)	0.047	0.041	0.058	0.055	0.047	0.072	0.081	1.294	
$C.D._{0.05}$	NS	NS	NS	0.162	0.138	0.212	0.238	3.816	
CV%	3.16	2.28	2.76	2.47	3.05	2.84	2.75	2.61	

* Figures in the parentheses are square root transformed values ($y= \sqrt{x}$), ** Figures in the parentheses are arc sine transformed values

Table 7. Changes in infected seeds (%) during germination of paddy seeds during 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Infected seeds (%)								
	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Mean
T_1 :Aniline blue	0.00	0.00	0.00	0.25	0.00	0.50	1.25	1.50	0.44
	(0.71)*	(0.71)*	(0.71)*	(0.87)*	(0.71)*	(1.00)*	(1.32)*	(1.41)*	
T_2 : Congo red	0.25	0.00	0.50	0.50	0.25	0.50	2.00	2.50	0.81
	(0.81)*	(0.71)*	(1.00)*	(1.00)*	(0.87)*	(1.00)*	(1.58)*	(1.73)*	
T_3 : Methyl violet	0.00	0.00	0.25	0.50	1.00	1.50	1.50	1.75	0.81
	(0.71)*	(0.71)*	(0.87)*	(1.00)*	(1.22)*	(1.41)*	(1.41)*	(1.50)*	
T_4 :Bromocresol purple	0.00	0.25	0.00	0.50	0.50	0.75	1.25	2.00	0.66
	(0.71)*	(0.87)*	(0.71)*	(1.00)*	(1.00)*	(1.12)*	(1.32)*	(1.58)*	
T_5 :Coomasie brilliant blue	0.00	0.00	0.00	0.75	1.50	1.25	1.75	2.50	0.97
	(0.71)*	(0.71)*	(0.71)*	(1.12)*	(1.41)*	(1.32)*	(1.50)*	(1.73)*	
T_6 : Beet (*Beta vulgaris*)	0.00	0.25	0.25	0.75	1.25	1.75	2.50	2.50	1.16
	(0.71)*	(0.87)*	(0.87)*	(1.12)*	(1.32)*	(1.50)*	(1.73)*	(1.73)*	
T_7 : Turmeric (*Curcuma longa*)	0.50	0.00	0.00	0.75	1.50	2.50	2.25	2.75	1.28
	(1.00)*	(0.71)*	(0.71)*	(1.12)*	(1.41)*	(1.73)*	(1.66)*	(1.80)*	
T_8 : Mehndi (*Lawosni ainermis*)	0.25	0.50	0.00	0.75	1.25	1.00	2.00	2.25	1.00
	(0.87)*	(1.00)*	(0.71)*	(1.12)*	(1.32)*	(1.22)*	(1.58)*	(1.66)*	
T_9 : Marigold (*Tagetes erecta*)	0.50	0.50	0.75	1.25	1.50	1.75	2.00	2.00	1.28
	(1.00)*	(1.00)*	(1.12)*	(1.32)*	(1.41)*	(1.50)*	(1.58)*	(1.58)*	
T_{10} : control	1.00	1.25	1.50	1.00	2.50	2.50	2.25	2.50	1.81
	(1.22)*	(1.32)*	(1.41)*	(1.22)*	(1.73)*	(1.73)*	(1.66)*	(1.73)*	
S.E.m (±)	0.185	0.336	0.305	0.298	0.481	0.384	0.327	0.282	
$C.D._{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	
CV%	2.36	2.99	2.80	3.09	2.42	2.67	1.85	2.58	

* Figures in the parentheses are square root transformed values [y= $\sqrt{(X+0.5)}$]

Table 8. Changes in insect infestation (%) of paddy seeds during 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Insect infestation (%)								
	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Mean
T_1 :Aniline blue	0.00	0.00	0.25	0.25	0.25	0.50	0.50	0.75	0.31
	(0.71)*	(0.71)*	(0.87)*	(0.87)*	(0.87)*	(1.00)*	(1.00)*	(1.12)*	
T_2 : Congo red	0.00	0.00	0.25	0.25	0.25	0.25	0.50	0.50	0.25
	(0.71)*	(0.71)*	(0.87)*	(0.87)*	(0.87)*	(0.87)*	(1.00)*	(1.00)*	
T_3 : Methyl violet	0.00	0.25	0.50	0.50	0.50	0.50	0.75	1.00	0.50
	(0.71)*	(0.87)*	(1.00)*	(1.00)*	(1.00)*	(1.00)*	(1.12)*	(1.22)*	
T_4 :Bromocresol purple	0.00	0.00	0.25	0.25	0.50	0.50	0.75	0.75	0.38
	(0.71)*	(0.71)*	(0.87)*	(0.87)*	(1.00)*	(1.00)*	(1.12)*	(1.12)*	
T_5 :Coomasie brilliant blue	0.00	0.25	0.25	0.25	0.25	0.50	0.50	1.00	0.38
	(0.71)*	(0.87)*	(0.87)*	(0.87)*	(0.87)*	(1.00)*	(1.00)*	(1.22)*	
T_6 : Beet (*Beta vulgaris*)	0.00	0.00	0.25	0.25	0.50	0.75	0.75	0.75	0.41
	(0.71)*	(0.71)*	(0.87)*	(0.87)*	(1.00)*	(1.12)*	(1.12)*	(1.12)*	
T_7 : Turmeric (*Curcuma longa*)	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.09
	(0.71)*	(0.71)*	(0.71)*	(0.71)*	(0.71)*	(0.87)*	(0.87)*	(0.87)*	
T_8 : Mehndi (*Lawosni ainermis*)	0.00	0.00	0.25	0.25	0.25	0.50	0.50	0.50	0.28
	(0.71)*	(0.71)*	(0.87)*	(0.87)*	(0.87)*	(1.00)*	(1.00)*	(1.00)*	
T_9 : Marigold (*Tagetes erecta*)	0.00	0.00	0.00	0.25	0.25	0.25	0.50	0.50	0.22
	(0.71)*	(0.71)*	(0.71)*	(0.87)*	(0.87)*	(0.87)*	(1.00)*	(1.00)*	
T_{10} : control	0.00	0.25	0.25	0.50	0.50	0.50	0.75	1.00	0.47
	(0.71)*	(0.87)*	(0.87)*	(1.00)*	(1.00)*	(1.00)*	(1.12)*	(1.22)*	
S.E.m (±)	0.000	0.057	0.126	0.118	0.123	0.069	0.063	0.085	
$C.D._{0.05}$	NS	NS	NS	NS	NS	0.203	0.186	0.251	
CV%	0.00	2.84	2.64	2.10	2.46	3.20	2.57	2.90	

* Figures in the parentheses are square root transformed values [y= $\sqrt{(X+0.5)}$]

(mean value of 0.25%) with regards to controlling the storage insects.

Hence, to summarise the experiment, it can be mentioned that all of the dye treatments, both artificial and natural, had a slight deleterious effect on storability of paddy seeds, as compared to control, though in some cases the differences were statistically non-significant. None of the dyes had any beneficial effect on germination or vigour parameters. However, among the artificial dyes, least deleterious effect was observed in case of seeds treated with Bromocresol purple and Congo red in all the crop species, in terms of various physiological parameters like germinability, percent abnormal seedlings, seed vigour indices and field emergence. Among natural dyes, mehndi and marigold treated seeds gave better results than the beet and turmeric treated seeds, in terms of the physiological parameters. However, seeds coloured with turmeric showed significantly lower insect infestation throughout the period of storage, as compared to the other treatments and control, clearly indicating its role in control of insect infestation during storage. Maximum deleterious effect of seed physiological parameters was recorded in case of Aniline blue and Methyl violet.

Considering the above findings from the investigation, it can be concluded that among artificial dyes, Bromocresol purple and Congo red can safely be recommended for seed colouring in paddy seeds. In case of natural dyes mehndi leaf extract and marigold petal extract proved to be good options for colouring of crop seeds. However, further investigations encompassing several other dyes may be taken up to have better screening of the artificial and natural dyes, as well as to fix seed colouring standards.

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