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Effect of seed colouring with natural and artificial dyes on storability of maize 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 maize seeds. Freshly harvested maize seeds were treated with fungicide (Thiram @ 2g kg^{-1} seed), followed by colouring with five artificial dyes @ 0.75% concentration, viz. Aniline blue, Congo red, Methyl violet, Bromocresol purple and Coomasie brilliant blue, and four natural dyes, viz. 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 (12.0%) 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, per cent 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.

***Keywords*:** Seed colouring, seed quality, seed storability

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 Erichro black-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). Harinath Babu *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 per cent 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-mentioned studies 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

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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 maize seeds and identify various dye(s) suitable for colouring of different crop seeds *vis à vis* seed storability.

MATERIALS AND METHODS

Freshly harvested maize seeds were treated with fungicide (Thiram @ 2g kg^{-1} seed), followed by colouring with five artificial dyes @ 0.75 per cent 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 maize (12.0%) 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 (Abdul-Baki and Anderson, 1973), 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.

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 (over 8 months) was slightly higher in T_7 (turmeric), the difference with other treatments being non-significant.

Seed germination among all the treatments decreased gradually with the increase in storage period. The germination potential of T_{10} (Control), *i.e.* seed treated with fungicide only and without any colouring, was higher over 8 months of storage (Table 2). 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) and 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_1 (Aniline blue) and T_3 (Methyl violet). The two treatments also recorded the highest percent decrease in SVI-I values over 8 months of storage, thus suggesting some deleterious effect of the two treatments of seed viability maintenance during storage.

Highest speed of germination value was recorded in case of T_3 (Methyl violet), followed by T_6 (Beet) and T_2 (Congo red) (Table 4). The percent decrease in speed of germination was highest in T_9 (Marigold), followed by T_7 (Turmeric).

In comparison to the dye treatments, highest germination percentage after accelerated ageing 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 germination after accelerated ageing, while T_1 (Aniline blue) and T_3 (Methyl violet) recorded the least germination value.

Highest field emergence was recorded in case of T_{10} (Control), 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), followed by T_4 (Bromocresol purple). Lowest field emergence values were observed in case of T_1 (Aniline blue) and T_3 (Methyl violet), clearly indicating maximum deleterious effect of the seeds, proportionate with the observations on germination percentage after accelerated ageing.

The percent infected seeds were found to be higher in T_{10} (Control) as well as all the natural dyes, as compared to the artificial dye, 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_2 (Congo red), followed by T_5 (Coomasie brilliant blue).

Among all the treatments, least insect infestation was recorded in case of T_7 (Turmeric), followed by T_9 (Marigold) (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_4 (Bromocresol purple) gave better result 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 maize seeds, as compared to control, though in some cases the differences were statistically non-significant. None of the dyes had any beneficial effect on

Table 1 : Changes in moisture content (%) of maize seeds over 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Moisture content (%)								Mean
	Oct '14	Nov '14	Dec '14	Jan '15	Feb '15	Mar '15	Apr '15	May '15	
T_1 : Aniline blue	10.98	11.15	11.13	11.28	11.71	11.57	11.69	11.78	11.41
T_2 : Congo red	11.21	11.10	11.36	11.57	11.48	11.66	11.58	11.22	11.40
T_3 : Methyl violet	11.16	11.60	11.45	11.32	11.39	11.52	11.46	11.43	11.42
T_4 : Bromocresol purple	12.24	11.28	11.54	11.45	11.21	11.35	11.39	11.38	11.36
T_5 : Coomasie brilliant blue	11.56	11.25	11.28	11.37	11.40	11.56	11.58	11.62	11.45
T_6 : Beet (*Beta vulgaris)*	10.89	11.12	11.08	11.25	11.31	11.45	11.51	11.61	11.28
T_7 : Turmeric (*Curcuma longa*)	11.08	11.19	11.31	11.48	11.50	11.65	11.80	11.88	11.49
T_8 : Mehndi (*Lawsonia inermis*)	11.32	11.56	11.38	11.31	11.41	11.66	11.61	11.67	11.49
T_9 : Marigold (*Tagetes erecta*)	11.18	11.02	11.15	11.48	11.36	11.31	11.43	11.48	11.30
T_{10} : Control	11.01	11.22	11.13	11.58	11.66	11.51	11.36	11.35	11.35
SEm (±)	**0.436**	**0.559**	**0.861**	**0.472**	**0.499**	**0.624**	**0.771**	**0.613**	
LSD(0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
CV	**2.66**	**1.94**	**3.11**	**2.86**	**2.54**	**1.87**	**2.63**	**3.01**	

Table 2 : Changes in germination (%) of maize seeds over 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Germination (%)								Mean
	Oct '14	Nov '14	Dec '14	Jan '15	Feb '15	Mar '15	Apr '15	May '15	
T_1 : Aniline blue	97.00	96.50	94.25	91.50	90.50	87.25	85.75	83.00	90.72
	(9.85)*	(9.82)*	(9.71)*	(9.57)*	(9.51)*	(9.34)*	(9.26)*	(9.11)*	
T_2 : Congo red	96.25	95.75	94.50	93.50	92.75	92.25	92.00	91.50	93.56
	(9.81)*	(9.79)*	(9.72)*	(9.67)*	(9.63)*	(9.60)*	(9.59)*	(9.57)*	
T_3 : Methyl violet	96.50	94.50	93.25	91.25	90.75	87.75	86.25	82.75	90.38
	(9.82)*	(9.72)*	(9.66)*	(9.55)*	(9.53)*	(9.37)*	(9.29)*	(9.10)*	
T_4 : Bromocresol purple	96.75	96.00	95.25	93.25	93.00	92.75	92.25	91.50	93.84
	(9.84)*	(9.80)*	(9.76)*	(9.66)*	(9.64)*	(9.63)*	(9.60)*	(9.57)*	
T_5 : Coomasie brilliant blue	96.50	96.25	95.25	93.75	92.25	91.75	91.00	89.00	93.22
	(9.82)*	(9.81)*	(9.76)*	(9.68)*	(9.60)*	(9.58)*	(9.54)*	(9.43)*	
T_6 : Beet (*Beta vulgaris)*	97.00	96.25	95.75	94.50	93.00	91.75	89.25	84.75	92.78
	(9.85)*	(9.81)*	(9.79)*	(9.72)*	(9.64)*	(9.58)*	(9.45)*	(9.21)*	
T_7 : Turmeric (*Curcuma longa*)	96.75	95.50	94.25	94.00	91.75	91.25	89.25	85.50	92.28
	(9.84)*	(9.77)*	(9.71)*	(9.70)*	(9.58)*	(9.55)*	(9.45)*	(9.25)*	
T_8 : Mehndi (*Lawsonia inermis*)	97.25	96.50	96.00	95.50	92.50	91.75	89.50	86.50	93.19
	(9.86)*	(9.82)*	(9.80)*	(9.77)*	(9.62)*	(9.58)*	(9.46)*	(9.30)*	
T_9 : Marigold (*Tagetes erecta*)	96.75	96.00	94.75	94.50	94.00	93.00	91.50	90.25	93.84
	(9.84)*	(9.80)*	(9.73)*	(9.72)*	(9.70)*	(9.64)*	(9.57)*	(9.50)*	
T_{10} : Control	97.25	96.50	96.00	95.75	95.00	94.00	93.25	93.00	
	(9.86)*	(9.82)*	(9.80)*	(9.79)*	(9.75)*	(9.70)*	(9.66)*	(9.64)*	95.09
SEm (±)	**0.093**	**0.106**	**0.072**	**0.058**	**0.070**	**0.108**	**0.101**	**0.145**	
LSD(0.05)	**NS**	**NS**	**NS**	**0.171**	**0.206**	**0.318**	**0.297**	**0.427**	
CV	**2.73**	**3.32**	**2.66**	**2.15**	**2.84**	**2.79**	**1.94**	**2.36**	

** Figures in the parentheses are square root transformed values (y="x)*

Table 3 : Changes in seed vigour index-I of maize seeds over 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Seed Vigour Index - I								Mean
	Oct '14	Nov '14	Dec '14	Jan '15	Feb '15	Mar '15	Apr '15	May '15	
T_1 : Aniline blue	3979.9	3919.8	3751.8	3569.5	3424.6	3235.6	3148.2	2984.5	3501.73
T_2 : Congo red	3865.9	3768.9	3682.5	3570.6	3435.7	3348.9	3306.4	3222.7	3525.20
T_3 : Methyl violet	3753.9	3639.3	3517.1	3352.2	3266.1	3098.0	2981.0	2804.3	3301.46
T_4 : Bromocresol purple	3439.5	3347.3	3220.2	3089.2	3019.0	2950.1	2874.5	2800.8	3092.59
T_5 : Coomasie brilliant blue	3599.0	3521.1	3447.9	3292.6	3172.0	3099.8	3002.8	2882.5	3252.22
T_6 : Beet (*Beta vulgaris)*	3756.8	3656.6	3563.8	3429.2	3270.4	3177.0	3032.7	2821.9	3338.56
T_7 : Turmeric (*Curcuma longa*)	3850.2	3726.4	3601.8	3523.7	3365.5	3245.7	3116.2	2927.1	3419.57
T_8 : Mehndi (*Lawsonia inermis*)	4229.4	4147.9	4054.0	3944.8	3748.0	3641.3	3450.4	3261.3	3809.63
T_9 : Marigold (*Tagetes erecta*)	3688.6	3609.8	3489.0	3423.2	3308.2	3205.5	3096.4	2990.8	3351.44
T_{10} : Control	4072.3	3964.2	3903.5	3819.4	3663.9	3560.7	3459.8	3381.2	3728.13
SEm (±)	**144.52**	**135.17**	**121.25**	**137.91**	**123.01**	**148.54**	**142.26**	**132.75**	
LSD(0.05)	**426.32**	**398.76**	**357.69**	**406.84**	**362.88**	**438.19**	**419.67**	**391.62**	
CV	**2.57**	**2.88**	**2.12**	**3.36**	**2.58**	**2.91**	**1.90**	**2.64**	

Table 4 : Changes in speed of germination of maize seeds over 8 months of storage under ambient condition as influenced by seed colouring

	Speed of Germination (%)								Mean
	Oct '14	Nov '14	Dec '14	Jan '15	Feb '15	Mar '15	Apr '15	May '15	
T_1 : Aniline blue	18.78	18.22	17.67	17.32	16.80	16.29	15.80	15.33	17.03
T_2 : Congo red	12.41	12.16	11.80	11.68	11.33	10.99	10.66	10.34	11.42
T_3 : Methyl violet	14.38	13.95	13.53	13.12	12.73	12.35	11.98	11.62	12.96
T_4 : Bromocresol purple	12.60	12.10	11.73	11.50	11.15	10.82	10.49	10.18	11.32
T_5 : Coomasie brilliant blue	14.11	13.97	13.55	13.01	12.62	12.24	11.87	11.52	12.86
T_6 : Beet (*Beta vulgaris)*	15.57	15.26	14.80	14.50	14.07	13.65	13.24	12.84	14.24
T_7 : Turmeric (*Curcuma longa*)	17.78	17.07	16.56	16.06	15.58	15.11	14.66	14.22	15.88
T_8 : Mehndi (*Lawsonia inermis*)	15.61	15.14	14.69	14.54	14.10	13.68	13.27	12.87	14.24
T_9 : Marigold (*Tagetes erecta*)	11.89	11.41	11.07	10.74	10.42	10.11	9.80	9.51	10.62
T_{10} : Control	14.09	13.95	13.53	13.40	12.99	12.60	12.23	11.86	13.08
SEm (±)	**1.580**	**1.462**	**1.307**	**1.424**	**1.338**	**1.248**	**1.475**	**1.383**	
LSD(0.05)	**4.662**	**4.314**	**3.857**	**4.201**	**3.946**	**3.683**	**4.351**	**4.079**	
CV	**2.52**	**2.08**	**3.67**	**2.85**	**2.92**	**2.43**	**2.58**	**2.15**	

Table 5 : Changes in germination after accelerated ageing of maize seeds over 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Germination (%) after accelerated ageing								Mean
	Oct '14	Nov '14	Dec '14	Jan '15	Feb '15	Mar '15	Apr '15	May '15	
T_1 : Aniline blue	73.25 (8.56)*	70.50 (57.10)**	67.50	64.25	62.75	58.25	57.75	53.25	63.44
T_2 : Congo red	72.25 (8.50)*	70.25 (56.95)**	67.00	65.50	63.00	62.50	61.25	59.75	65.19
T_3 : Methyl violet	72.50 (8.51)*	69.50 (56.48)**	66.00	64.75	62.75	59.25	57.00	53.25	63.13
T_4 : Bromocresol purple	73.25 (8.56)*	70.75 (57.26)**	68.75	65.50	63.25	62.00	61.25	59.00	65.47
T_5 : Coomasie brilliant blue	72.50 (8.51)*	70.00 (56.79)**	68.25	66.50	63.25	62.00	60.50	57.75	65.09
T_6 : Beet (*Beta vulgaris)*	73.00 (8.54)*	70.75 (57.26)**	68.75	66.25	63.75	61.25	59.75	54.50	64.75
T_7 : Turmeric (*Curcuma longa*)	73.75 (8.59)*	70.75 (57.26)**	67.50	66.75	62.50	61.75	59.75	55.25	64.75
T_8 : Mehndi (*Lawsonia inermis*)	73.50 (8.57)*	70.00 (56.79)**	68.50	67.50	63.00	61.75	59.25	55.00	64.81
T_9 : Marigold (*Tagetes erecta*)	73.75 (8.59)*	70.25 (56.95)**	67.00	66.25	64.75	62.25	61.50	58.25	65.50
T_{10} : Control	73.00 (8.54)*	71.50 (57.73)**	68.25	67.75	65.25	63.50	62.00	60.75	66.50
SEm (±)	**0.041**	**0.539**	**0.699**	**0.725**	**0.895**	**0.993**	**1.063**	**1.180**	
LSD(0.05)	**NS**	**NS**	**2.063**	**2.138**	**2.640**	**2.929**	**3.136**	**3.482**	
CV	**3.20**	**2.35**	**2.76**	**2.42**	**2.89**	**2.66**	**2.09**	**3.10**	

** Figures in the parentheses are square root transformed values (y="x) ** Figures in the parentheses are arc sine transformed values*

Table 6 : Changes in field emergence of maize seeds over 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Field emergence (%)								Mean
	Oct '14	Nov '14	Dec '14	Jan '15	Feb '15	Mar '15	Apr '15	May '15	
T_1 : Aniline blue	89.25 (9.45)*	88.75 (9.42)*	85.75 (9.26)*	83.25 (9.12)*	81.50 (9.03)*	78.50 (8.86)*	76.25 (8.73)*	73.75 (8.59)*	82.13
T_2 : Congo red	88.50 (9.41)*	88.00 (9.38)*	86.00 (9.27)*	85.00 (9.22)*	83.50 (9.14)*	83.00 (9.11)*	82.00 (9.06)*	81.50 (9.03)*	84.69
T_3 : Methyl violet	88.75 (9.42)*	87.00 (9.33)*	84.75 (9.21)*	83.00 (9.11)*	81.50 (9.03)*	79.00 (8.89)*	76.75 (8.76)*	73.50 (8.57)*	81.78
T_4 : Bromocresol purple	89.00 (9.43)*	88.50 (9.41)*	86.75 (9.31)*	85.00 (9.22)*	83.75 (9.15)*	83.50 (9.14)*	82.00 (9.06)*	81.50 (9.03)*	85.00
T_5 : Coomasie brilliant blue	88.75 (9.42)*	88.75 (9.42)*	86.50 (9.30)*	85.50 (9.25)*	83.00 (9.11)*	82.75 (9.10)*	81.00 (9.00)*	79.25 (8.90)*	84.44
T_6 : Beet (*Beta vulgaris)*	89.25 (9.45)*	88.50 (9.41)*	87.25 (9.34)*	86.00 (9.27)*	83.75 (9.15)*	82.50 (9.08)*	79.50 (8.92)*	75.50 (8.69)*	84.03
T_7 : Turmeric (*Curcuma longa*)	89.00 (9.43)*	88.00 (9.38)*	85.75 (9.26)*	85.50 (9.25)*	82.50 (9.08)*	82.00 (9.06)*	79.50 (8.92)*	76.25 (8.73)*	83.56
T_8 : Mehndi (*Lawsonia inermis*)	89.50 (9.46)*	88.50 (9.41)*	87.50 (9.35)*	86.75 (9.31)*	83.25 (9.12)*	82.50 (9.08)*	79.75 (8.93)*	77.00 (8.77)*	84.34
T_9 : Marigold (*Tagetes erecta*)	89.00 (9.43)*	88.50 (9.41)*	86.25 (9.29)*	86.25 (9.29)*	84.75 (9.21)*	83.75 (9.15)*	81.50 (9.03)*	80.50 (8.97)*	85.06
T_{10} : Control	89.50 (9.46)*	89.00 (9.43)*	87.50 (9.35)*	87.25 (9.34)*	85.50 (9.25)*	84.75 (9.21)*	83.00 (9.11)*	82.75 (9.10)*	86.16
SEm (±)	**0.058**	**0.049**	**0.063**	**0.054**	**0.050**	**0.081**	**0.090**	**0.108**	
LSD(0.05)	**NS**	**NS**	**NS**	**0.158**	**0.147**	**0.238**	**0.266**	**0.319**	
CV	**2.88**	**1.69**	**1.84**	**2.54**	**2.37**	**3.02**	**2.66**	**2.83**	

** Figures in the parentheses are square root transformed values (y="x) ** Figures in the parentheses are arc sine transformed values*

Table 7 : Changes in infected seeds during germination of maize seeds over 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Infected seeds (%)								Mean
	Oct '14	Nov '14	Dec '14	Jan '15	Feb '15	Mar '15	Apr '15	May '15	
T_1 : Aniline blue	0.00 (0.71)*	0.25 (0.87)*	0.50 (1.00)*	1.25 (1.32)*	2.50 (1.73)*	2.50 (1.73)*	2.00 (1.58)*	2.50 (1.73)*	1.44
T_2 : Congo red	0.00 (0.71)*	0.00 (0.71)*	0.00 (0.71)*	0.25 (0.87)*	1.25 (1.32)*	1.50 (1.41)*	1.75 (1.50)*	1.75 (1.50)*	0.81
T_3 : Methyl violet	0.00 (0.71)*	0.25 (0.87)*	0.00 (0.71)*	0.75 (1.12)*	0.75 (1.12)*	1.50 (1.41)*	1.50 (1.41)*	2.50 (1.73)*	0.91
T_4 : Bromocresol purple	0.25 (0.87)*	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	1.00 (1.32)*	1.75 (1.50)*	1.50 (1.41)*	3.00 (1.87)*	1.00
T_5 : Coomasie brilliant blue	0.00 (0.71)*	0.00 (0.71)*	0.00 (0.71)*	0.75 (1.12)*	0.50 (1.00)*	2.00 (1.58)*	2.50 (1.73)*	2.75 (1.80)*	1.06
T_6 : Beet (*Beta vulgaris)*	0.50 (1.00)*	0.25 (0.87)*	0.25 (0.87)*	1.00 (1.22)*	0.50 (1.00)*	1.50 (1.41)*	1.75 (1.50)*	2.50 (1.73)*	1.19
T_7 : Turmeric (*Curcuma longa*)	0.25 (0.87)*	0.00 (0.71)*	0.00 (0.71)*	0.50 (1.00)*	1.75 (1.50)*	2.25 (1.66)*	2.75 (1.80)*	2.50 (1.73)*	1.19
T_8 : Mehndi (*Lawsonia inermis*)	0.00 (0.71)*	0.00 (0.)71*	0.25 (0.87)*	0.25 (0.87)*	1.25 (1.32)*	1.75 (1.50)*	2.25 (1.66)*	3.00 (1.87)*	1.13
T_9 : Marigold (*Tagetes erecta*)	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.50 (1.00)*	1.50 (1.41)*	2.50 (1.73)*	2.50 (1.73)*	2.75 (1.80)*	1.28
T_{10} : Control	0.00 (0.71)*	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.75 (1.12)*	1.25 (1.32)*	2.00 (1.58)*	3.00 (1.87)*	0.97
SEm (±)	**0.214**	**0.186**	**0.271**	**0.260**	**0.049**	**0.437**	**0.288**	**0.218**	
LSD(0.05)	**NS**	**NS**	**NS**	**NS**	**0.146**	**NS**	**NS**	**NS**	
CV	**2.88**	**2.32**	**2.60**	**1.91**	**2.08**	**2.81**	**2.83**	**2.35**	

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

Table 8 : Changes in insect infestation of maize seeds over 8 months of storage under ambient condition as influenced by seed colouring

Treatment	Infected seeds (%)								Mean
	Oct '14	Nov '14	Dec '14	Jan '15	Feb '15	Mar '15	Apr '15	May '15	
T_1 : Aniline blue	0.00 (0.71)*	0.00 (0.71)*	0.50 (1.00)*	0.50 (1.00)*	0.50 (1.00)*	0.75 (1.12)*	1.00 (1.22)*	1.25 (1.32)*	0.56
T_2 : Congo red	0.00 (0.71)*	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.25 (0.87)*	0.50 (1.00)*	0.50 (1.00)*	1.00 (1.22)*	0.34
T_3 : Methyl violet	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.50 (1.00)*	0.75 (1.12)*	0.75 (1.12)*	1.00 (1.22)*	1.00 (1.22)*	0.56
T_4 : Bromocresol purple	0.00 (0.71)*	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.25 (0.87)*	0.05 (1.00)*	0.75 (1.12)*	0.75 (1.12)*	0.34
T_5 : Coomasie brilliant blue	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.50 (1.00)*	0.75 (1.12)*	0.75 (1.12)*	1.00 (1.22)*	1.50 (1.41)*	0.63
T_6 : Beet (*Beta vulgaris)*	0.00 (0.71)*	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.50 (1.00)*	0.75 (1.12)*	1.25 (1.32)*	1.25 (1.32)*	0.53
T_7 : Turmeric (*Curcuma longa*)	0.00 (0.71)*	0.00 (0.71)*	0.00 (0.71)*	0.00 (0.71)*	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.50 (1.00)*	0.13
T_8 : Mehndi (*Lawsonia inermis*)	0.00 (0.71)*	0.00 (0.)71*	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.75 (1.12)*	0.75 (1.12)*	0.75 (1.12)*	0.34
T_9 : Marigold (*Tagetes erecta*)	0.00 (0.71)*	0.00 (0.71)*	0.71 (0.00)*	0.25 (0.87)*	0.25 (0.87)*	0.50 (1.00)*	0.50 (1.00)*	0.75 (1.12)*	0.28
T_{10} : Control	0.00 (0.71)*	0.25 (0.87)*	0.25 (0.87)*	0.50 (1.00)*	0.75 (1.12)*	0.75 (1.12)*	1.25 (1.32)*	1.25 (1.32)*	0.63
SEm (±)	**0.000**	**0.119**	**0.131**	**0.126**	**0.049**	**0.052**	**0.097**	**0.088**	
LSD(0.05)	**NS**	**NS**	**NS**	**NS**	**0.146**	**0.152**	**0.286**	**0.261**	
CV	**0.00**	**2.11**	**1.88**	**2.34**	**2.08**	**3.21**	**2.56**	**2.84**	

** Figures in the parentheses are square root transformed values [y="(x+0.5)]*

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 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 colouring of maize seeds. In case of natural dyes, mehndi leaf extract and marigold petal extract proved to be good options for colouring of maize 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. Similarly, calculating the cost of dye treatment and benefits arising out of it may need further study.

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