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Enhancement of seed quality attributes through biopriming in cucumber (*Cucumis sativus* L.)

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Abstract
Priming was done by using high and low vigour seeds with cow dung slurry, vermiwash, *Azospirillum*, PSB and *Tricoderma viridae*, at two temperature conditions. High vigour seeds recorded significantly higher seed quality attributes like first and final count germination, Bartlett rate index (BRI) an indicative of speed of germination, mean seedling length (MSL), mean seedling dry weight (MSDW), seedling vigour index (SVI- I) and SVI- II (84.94%, 89.83%, 0.533, 28.48 cm, 9.97 mg, 2562 and 899, respectively). The T_{50} value and mean germination time (MGT) were also lower (1.19days and 1.65days) in high vigour seeds. Among the biological agents tested, significantly higher first and final count germination, BRI, MSL, MSDW, SVI- I and SVI- II (84.67%, 87.42%, 0.526,30.38 cm, 10.47 mg, 2652 and 915, respectively) was registered in PSB primed seeds. The T_{50} value and mean germination time (MGT) were also lower (1.42 days and 1.77 days) in PSB primed seeds. The best performed biological agents were cow dung slurry followed by PSB, Vermiwash, *Tricoderma viridae* and *Azospirillum* in the order of their performance, when seeds primed at the temperature of 25± 1 ^{0}C.

Keywords: Cucumber, priming, vigour, seed quality, biological agents

Introduction
Cucumber (*Cucumis sativus* L.) is one of the most important cucurbitaceous vegetable grown throughout the world. The crop has a wide range of utilities such as pickling, salad, cooked vegetable as an ingredient in Unani medicines and cosmetics. The wide gap in productivity in India when compared to world can be attributed to the lack of availability of quality seeds of high yielding varieties, promising hybrids and parthenocarpic varieties suited for glass or poly house cultivation. Seed quality is one of the key factors affecting the successful farming, but this seed trait inevitably declines during prolonged storage. Seed priming is a pre-sowing treatment that involves controlled hydration of seeds, sufficient to allow pre germinative metabolic events to take place and to restrict radical protrusion through the seed coat (Heydecker *et al*., 1973) [12]. This technique has been used in some vegetables seeds including cucumber to augment the germination rate, total germination and seedling uniformity etc., mainly under unfavourable environmental conditions. It is a useful technique to exploit seed potential in arid and desert ecosystem. The knowledge gained on the repair mechanisms that take place upon various priming treatments has been used in many crops in seed industry.
The use of chemical pesticides in agriculture and horticulture is becoming more restricted due to environmental and health concerns and many active ingredients are being banned. Seeds treated with microorganisms can be considered either as a direct alternative to chemical seed treatment, or as part of an integrated system, combining both microorganisms and pesticides (possibly at a reduced dose). In recent days, bio priming is gaining much importance among different priming methods in improving planting value of seeds. Biopriming is soaking or treating seeds with various biological agents like, *Rhizobium*, *Azospirillu*m, Phosphorous Solubilising Bacteria (PSB), etc. Biological control agents added to seeds before or during priming ("bio-priming") would proliferate to provide greater protection against soil borne pathogens than adding these agents after seed priming or to non-primed seeds. A viable option for the use of beneficial microorganisms in horticulture and agriculture is application to seed, which is rather very cheap and safer. Because this specifically targets the area where most benefit may be seen during seedling establishment and beneficial microbial colonization of the rhizosphere may further promote plant growth during the growing season (Harman, 1991) [10]. Plant growth-promoting rhizobacteria (PGPR) would act as resistance-inducers in many crop species.

Most reported strains of PGPR are from *Pseudomonas* spp., especially *Pseudomonas fluorescens* strains. These can enhance plant growth and protect the plants from various plant pathogens in several crops such as cucumber, radish, tomato, sugar cane and rice (Liu *et al*., 1995) [14]. Harman and Taylor (1988) [9] applied *Trichoderma harzianum* to cucumber seeds as an aqueous slurry, then added the solid matrix (lignaceous shale) and water and incubated this mixture for 4 days at 20^0C (solid matrix priming). The number of *Trichoderma* propagules increased 10-fold during priming to 10^3–10^4 colony forming units (CFUs) per seed, these levels were sustained even after drying and a few days of storage. Following priming with a solid matrix of lignaceous shale (Agro- Lig), these seeds gave 96 per cent emergence when compared to 64 per cent recorded with the aqueous slurry alone in *Phythium ultimum* infested soil. Including *Trichoderma harzianum* during priming rather than Thiram fungicide gave greater seedling emergence. The slurry technique is a common method for applying bio-protectants to seeds (Taylor and Harman, 1990) [18] and consists of mixing the bio-protectant with an aqueous binder and applying this mixture to seeds. Applying a *Trichoderma harzianum* suspension to cucumber seeds (without a binder) failed to provide protection against *Pythium ultimum* (Taylor *et al*., 1991) [19]. Therefore, these binder or coating materials may provide a food base for the *Trichoderma*. Microorganisms that are frequently surviving and proliferating at high numbers on the seed can be added to the water used to hydrate the seed during drum priming, (Wright *et al*., 2003; Bennett and Whipps, 2008) [20, 4]. Many fungal bio-control agents, including *Trichoderma*, are applied to seed as conidia or resting spores which must become active before interaction with the pathogen. The active fungal agent must persist in the spermoplane or spermosphere in sufficient quantity to protect the germinating seed (Harman, 2006; Neumann and Laing, 2006) [11, 15]. Pill *et al*. (2009) [16] reported that slurry coating of non primed or osmotically primed cucumber seeds with *Trichoderma harzianum* and *Trichoderma viridae* or combination of both reduced percentage of damping-off disease and increased the final emergence percentage up to 58.10 per cent and greater seedling fresh weight. Therefore an attempt has been made to enhance the seed quality attributes of cucumber through biopriming.

Material and Methods

Freshly harvested and graded cucumber seeds of cv. INDAM-11 were obtained from the M/S Indo American Hybrid Seeds Pvt., Ltd., Bangalore. The seeds were dried to reduce the moisture to safe level (<6%) and they were stored at 4^0C in refrigerator till the completion of the experiment. Fresh cucumber seeds were subjected to accelerated ageing (AA) test as per Delouche and Baskin (1973) [6] to create lots of two vigour levels, *viz*., high vigour (V_1:>90% germination) and low vigour (V_2:<60% germination) levels seeds were soaked in biogas slurry and vermi-wash solution in the ratio of 1:2 (W/V) at two different temperatures (T_1- 25±1^{0}C; T_2- 10±1^{0}C) for a period of 48 h. Further, seeds were treated with biological agents such as *Azospirillum*, Phosphorous Solubilising Bacteria (PSB) and *Trichoderma viridae* with one per cent Carboxy Methyl Cellulose as binding agent and left for drying at different temperatures for a period of 48 h. Then seeds were surface dried at room temperature and used for the experiment. The experimental data were statistically analyzed as per the methods outlined by Sundararaj *et al*. (1972) [17] by adopting "Fisher's Analysis of Variance Techniques". Critical difference (CD) values were computed at 1 per cent level wherever 'F' test was significant. The following observations were recorded for the evaluation of seed quality due to biopriming.

Seed moisture content (%): Moisture content of seed sample was determined by gravimetric method by using high constant temperature oven method as per ISTA (2015) [13]. Two grams of seeds were taken in aluminium containers and kept in a hot air oven maintained at 130± 2^0 C for a period of one hour. Then the samples were cooled in desiccators over silica gel for 30 to 45 minutes. The cooled samples were weighed and the seed moisture content was expressed in percentage on wet weight basis using the following formula.

Moisture content (%) = $(W_2-W_3) / (W_2-W_1) \times 100$

Where, W_1 - weight of the empty aluminium container; W_2 – weight of the empty aluminium container + seeds before drying; W_3 - weight of the empty container + seeds after drying.

First and final counts of germination (%): The standard germination test was conducted in the laboratory using 'between paper' method as per ISTA (2015) [13]. Fifty seeds each of four replications were placed equidistantly on moist germination paper. The rolled towels were incubated in germination chamber maintained at 25^0±1^0C and 90 per cent relative humidity (RH). The first and the final counts were taken on 4th and 8th day of germination test, respectively. The percentage of germination was expressed based on the normal seedlings.

Mean germination time (MGT): It was calculated according to the equation of Ellis and Roberts (1981) [7] and expressed in days. The equation is as follows:

$MGT = \sum D\,n / \sum n$

Where, "D" is the number of days counted from the beginning of the test and "n" is the number of seeds that germinate on day 'D'.

Time to 50% germination (T_{50}): Time to get 50 per cent germination was calculated according to the formula of Coolbear *et al*. (1990) [5]. T_{50} was defined as days needed to reach 50 per cent of final germination percentage.

Speed of germination (BRI): Speed of germination was calculated as Bartlett's Rate Index (Bartlett, 1973) [3], which was worked out from the daily germination counts and calculated as follows:

$$BRI = \frac{P_1 + (P_1+P_2) + (P_1+P_2+P_3) + \ldots + (P_1+P_2+P_3+\ldots. +P_n)}{N\,(P_1 + P_2 + P_3 + \ldots + P_n)}$$

Where, $P_1 + P_2 + P_3 + \ldots\ldots$and P_n are the germination (%) at 1st, 2nd, 3rd and nth day, respectively and 'N' is the total number of days taken for germination.

Mean seedling length (cm): From the seeds kept for standard germination test, ten normal seedlings were randomly selected on final (8th day) counting and the seedling length was measured from root tip to shoot apex and the mean seedling

length was computed and expressed in centimeter.

Mean seedling dry weight (mg): Ten seedlings selected for seedling length measurement were used for recording seedling dry weight. After removing the cotyledons (remnant seed), seedlings were dried in hot air oven maintained at 80±2^{0}C for 18 hours and cooled in desiccators over silica gel. The mean seedling dry weight was recorded and expressed in milligrams per seedling.

Seedling vigour index (SVI) –I and II: Seedling Vigor Index (SVI) was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) [1] and expressed as whole number.

Results and Discussion

Seed moisture (%) and T_{50} value (days)

The moisture content of bioprimed seeds was significantly higher (6.22%) at 25ºC (T_1) and it was lower (6.06%) at 10ºC (T_2). Among the biological treatments, PSB (B_5) and untreated control (B_1) recorded higher (6.71%) and lower (5.10%) seed moisture, respectively.

Table 1: Seed moisture and T_{50} value as influenced by vigour levels and biopriming in cucumber.

Treatments		Seed moisture			T_{50} (days)		
		High Vigour (V_1)	Low Vigour (V_2)	Mean	High Vigour (V_1)	Low Vigour (V_2)	Mean
T_1- 25±1^{0}C	B_1	5.04	5.12	5.08	1.00	4.00	2.50
	B_2	6.36	6.55	6.46	1.00	2.00	1.50
	B_3	5.79	6.02	5.91	1.00	2.00	1.50
	B_4	6.42	6.18	6.30	1.33	2.33	1.83
	B_5	6.75	6.83	6.79	1.00	1.67	1.34
	B_6	6.77	6.83	6.80	1.33	2.67	2.00
T_2- 10±1^{0}C	B_1	5.12	5.12	5.12	1.67	4.00	2.84
	B_2	5.87	5.99	5.93	1.00	2.00	1.50
	B_3	5.68	5.83	5.76	1.00	2.00	1.50
	B_4	6.50	6.83	6.67	1.33	2.00	1.67
	B_5	6.82	6.43	6.63	1.00	2.00	1.50
	B_6	6.55	5.93	6.24	1.67	2.00	1.84
		V x T			**V x T**		
	T_1	6.19	6.26	6.22	1.11	2.44	1.78
	T_2	6.09	6.02	6.06	1.28	2.33	1.81
		V x B			**V x B**		
	B_1	5.08	5.12	5.10	1.33	4.00	2.67
	B_2	6.11	6.27	6.19	1.00	2.00	1.50
	B_3	5.74	5.93	5.83	1.00	2.00	1.50
	B_4	6.46	6.51	6.48	1.33	2.17	1.75
	B_5	6.79	6.63	6.71	1.00	1.83	1.42
	B_6	6.66	6.38	6.52	1.50	2.33	1.92
Mean		6.14	6.14	6.14	1.19	2.39	1.79
		S.Em±	CD (P=0.01)	CV (%)	S.Em±	CD (P=0.01)	CV (%)
V		0.028	NS		0.056	0.21	
T		0.028	0.10		0.056	NS	
B		0.048	0.18		0.096	0.36	
V x T		0.039	NS	2.70	0.079	0.37	6.60
V x B		0.048	0.18		0.136	0.51	
T x B		0.068	0.26		0.096	NS	
V x T x B		0.096	0.36		0.192	NS	

NS: Non Significant, Biological agents (B): B_1- Control; B_2- Cowdung slurry; B_3- Vermiwash; B_4- *Azospirillum*; B_5- PSB; B_6- *Trichoderma viridae.*

Among the interactions of V x B, V_1B_5 had registered higher (6.79%) seed moisture which was on par with V_1B_6 (6.66%), V_2B_5 (6.63%) and it was lowest (5.08%) in V_1B_1. Among T x B interactions, T_1B_6 recorded higher (6.80%) seed moisture, but it was on par with T_1B_5 (6.79%), T_2B_4 (6.67%) and T_2B_5 (6.63%). Among the vigour levels, lower T_{50} value (1.19 days) was recorded in V_1 and it was significantly higher (2.39 days) in V_2. Among the biological agents, lower T_{50} value (1.42 days) was noticed in B_5 that was statistically on par with and cow dung slurry (B_2) (1.50 days), vermiwash (B_3) (1.50 days) and *Azospirillum* (B_4) (1.75 days), however, it was significantly higher in B_1 (2.67 days). Similar findings were reported by Pill *et al*. (2009); Haluk *et al*. (2009) [16, 8].

Table 2: First and final count germination as influenced by vigour levels and biopriming in cucumber.

Treatments		First count germination (%)			Final count germination (%)		
		High Vigour (V_1)	Low Vigour (V_2)	Mean	High Vigour (V_1)	Low Vigour (V_2)	Mean
T_1- 25±1 ^{0}C	B_1	71.33	49.00	60.17	89.33	57.33	73.33
	B_2	96.00	77.33	86.67	96.67	82.00	89.34
	B_3	86.67	72.00	79.34	90.67	76.00	83.34
	B_4	77.33	64.00	70.67	78.67	73.33	76.00
	B_5	91.33	85.33	88.33	93.33	85.33	89.33

	B_6	88.00	65.33	76.67	90.67	69.33	80.00
T_2- 10± 1^0C	B_1	70.00	46.67	58.34	90.00	57.33	73.67
	B_2	86.67	73.33	80.00	90.33	73.33	81.83
	B_3	92.00	76.00	84.00	92.00	80.00	86.00
	B_4	82.67	68.00	75.34	82.67	79.33	81.00
	B_5	86.67	75.33	81.00	91.67	79.33	85.50
	B_6	90.67	72.00	81.34	92.00	77.33	84.67
	V x T				**V x T**		
	T_1	85.11	68.83	76.97	89.89	73.89	81.89
	T_2	84.78	68.56	76.67	89.78	74.44	82.11
	V x B				**V x B**		
	B_1	70.67	47.83	59.25	89.67	57.33	73.50
	B_2	91.33	75.33	83.33	93.50	77.67	85.58
	B_3	89.33	74.00	81.67	91.33	78.00	84.67
	B_4	80.00	66.00	73.00	80.67	76.33	78.50
	B_5	89.00	80.33	84.67	92.50	82.33	87.42
	B_6	89.33	68.67	79.00	91.33	73.33	82.33
Mean		84.94	68.69	76.82	89.83	74.17	82.00
		S.Em±	CD (P=0.01)	CV (%)	S.Em±	CD(P=0.01)	CV (%)
V		0.66	2.51		0.567	2.15	
T		0.66	NS		0.567	NS	
B		1.15	3.40		0.802	2.99	
V x T		0.94	4.35	5.17	0.982	3.72	4.15
V x B		1.15	4.35		0.982	3.72	
T x B		1.62	6.15		1.389	5.27	
V x T x B		2.30	NS		1.965	NS	

NS: Non Significant, Biological agents (B): B_1- Control; B_2- Cowdung slurry; B_3- Vermiwash; B_4- *Azospirillum*; B_5- PSB; B_6- *Trichoderma viridae*

Table 3: Mean germination time and speed of germination (BRI) as influenced by vigour levels and biopriming in cucumber.

Treatments		**Mean Germination Time (days)**			**Speed of germination (BRI)**		
		High Vigour (V_1)	**Low Vigour (V_2)**	**Mean**	**High Vigour (V_1)**	**Low Vigour (V_2)**	**Mean**
T_1- 25±1^0C	B_1	2.38	3.23	2.81	0.508	0.437	0.473
	B_2	1.23	2.02	1.63	0.553	0.511	0.532
	B_3	1.72	2.05	1.89	0.529	0.508	0.519
	B_4	1.48	2.41	1.95	0.537	0.494	0.516
	B_5	1.36	1.78	1.57	0.547	0.520	0.534
	B_6	1.55	2.32	1.94	0.536	0.496	0.516
T_2- 10±1^0C	B_1	2.65	3.30	2.98	0.490	0.436	0.463
	B_2	1.30	1.96	1.63	0.552	0.510	0.531
	B_3	1.19	2.13	1.66	0.553	0.503	0.528
	B_4	1.54	2.83	2.19	0.533	0.478	0.506
	B_5	1.65	2.27	1.96	0.537	0.500	0.519
	B_6	1.79	2.43	2.11	0.523	0.491	0.507
	V x T				**V x T**		
	T_1	1.62	2.30	1.96	0.535	0.494	0.515
	T_2	1.69	2.49	2.09	0.531	0.486	0.509
	V x B				**V x B**		
	B_1	2.52	3.26	2.89	0.499	0.436	0.468
	B_2	1.26	1.99	1.63	0.553	0.510	0.532
	B_3	1.46	2.09	1.77	0.541	0.505	0.523
	B_4	1.51	2.62	2.07	0.535	0.486	0.511
	B_5	1.50	2.03	1.77	0.542	0.510	0.526
	B_6	1.67	2.37	2.02	0.529	0.493	0.511
Mean		1.65	2.39	2.02	0.533	0.490	0.512
		S.Em±	CD (P=0.01)	CV (%)	S.Em±	CD (P=0.01)	CV (%)
V		0.029	0.11		0.001	0.005	
T		0.029	0.11		0.001	0.005	
B		0.050	0.19		0.002	0.008	
V x T		0.041	NS	8.62	0.007	NS	1.58
V x B		0.050	0.19		0.003	0.012	
T x B		0.071	0.27		0.003	NS	
V x T x B		0.101	NS		0.005	NS	

NS: Non Significant, Biological agents (B):B_1- Control; B_2- Cowdung slurry; B_3- Vermiwash; B_4- *Azospirillum*; B_5- PSB; B_6- *Trichoderma viridae*

Table 4: Mean seedling length and mean seedling dry weight as influenced by vigour levels and biopriming in Cucumber.

Treatments		Mean seedling length (cm)			Mean seedling weight (mg)		
		High Vigour (V_1)	Low Vigour (V_2)	Mean	High Vigour (V_1)	Low Vigour (V_2)	Mean
T_1- 25±1^{0}C	B_1	25.83	23.63	24.73	7.72	6.13	6.93
	B_2	29.85	28.21	29.03	11.40	10.73	11.07
	B_3	28.67	22.60	25.64	10.66	9.33	10.00
	B_4	29.67	22.51	26.09	9.93	8.00	8.97
	B_5	32.45	30.92	31.69	11.15	10.93	11.04
	B_6	28.87	20.75	24.81	10.73	9.07	9.90
T_2- 10±1^{0}C	B_1	21.02	25.53	23.28	7.47	6.34	6.91
	B_2	31.12	27.92	29.52	10.67	10.03	10.35
	B_3	27.93	27.90	27.92	9.83	9.50	9.67
	B_4	25.20	22.79	24.00	8.83	7.90	8.37
	B_5	33.62	24.52	29.07	11.57	8.23	9.90
	B_6	27.53	24.08	25.81	9.73	9.40	9.57
	V x T				**V x T**		
	T_1	29.22	24.77	27.00	10.27	9.03	9.65
	T_2	27.74	25.46	26.60	9.68	8.57	9.13
	V x B				**V x B**		
	B_1	23.43	24.58	24.00	7.59	6.23	6.91
	B_2	30.48	28.07	29.27	11.03	10.38	10.70
	B_3	28.30	25.25	26.77	10.25	9.41	9.83
	B_4	27.43	22.65	25.04	9.38	7.95	8.66
	B_5	33.03	27.72	30.38	11.36	9.58	10.47
	B_6	28.20	22.42	25.31	10.23	9.23	9.73
Mean		28.48	25.11	26.80	9.97	8.80	9.38
		S.Em±	CD (P=0.01)	CV (%)	S.Em±	CD (P=0.01)	CV (%)
V		0.186	0.70		0.080	0.30	
T		0.186	NS		0.080	0.30	
B		0.263	1.00		0.113	0.52	
V x T		0.322	1.22	4.16	0.138	0.52	5.09
V x B		0.322	1.22		0.138	NS	
T x B		0.456	1.72		0.195	NS	
V x T x B		0.645	2.44		0.276	1.04	

NS: Non Significant, Biological agents (B): B_1- Control; B_2- Cowdung slurry; B_3- Vermiwash; B_4- *Azospirillum*; B_5- PSB; B_6- *Trichoderma viridae*

Table 5: Seedling vigour index (SVI) -I and SVI-II as influenced by vigour levels and biopriming in cucumber.

Treatments		Seedling vigour index (SVI) - I			Seedling vigour index (SVI) - II		
		High Vigour (V_1)	Low Vigour (V_2)	Mean	High Vigour (V_1)	Low Vigour (V_2)	Mean
T_1- 25±1^{0}C	B_1	2308	1354	1831	689	351	520
	B_2	2885	2312	2598	1102	880	991
	B_3	2600	1721	2160	967	710	838
	B_4	2334	1651	1993	782	588	685
	B_5	3028	2636	2832	1040	932	986
	B_6	2617	1439	2028	973	627	800
T_2- 10±1^{0}C	B_1	1890	1466	1678	672	363	517
	B_2	2811	2050	2430	962	737	850
	B_3	2569	2230	2400	904	758	831
	B_4	2082	1807	1945	730	626	678
	B_5	3081	1860	2471	1060	625	843
	B_6	2533	1862	2197	896	726	811
	V x T				**V x T**		
	T_1	2629	1853	2241	926	682	804
	T_2	2495	1880	2187	871	640	755
	V x B				**V x B**		
	B_1	2099	1410	1755	681	357	519
	B_2	2848	2182	2515	1032	809	921
	B_3	2585	1976	2281	936	734	835
	B_4	2209	1730	1969	756	607	682
	B_5	3055	2249	2652	1051	779	915
	B_6	2575	1651	2113	935	677	806
Mean		2562	1866	2214	899	661	780
		S.Em±	CD (P=0.01)	CV (%)	S.Em±	CD (P=0.01)	CV (%)
V		23.28	88.3		9.46	35	
T		23.28	NS		9.46	35	

B	32.93	152		16.38	62	
V x T	40.33	NS	6.30	16.38	NS	7.27
V x B	40.33	152		16.38	NS	
T x B	57.03	216		23.17	52	
V x T x B	80.65	305		32.76	124	

NS: Non Significant, Biological agents (B): B_1- Control; B_2- Cowdung slurry; B_3- Vermiwash; B_4- *Azospirillum*; B_5- PSB; B_6- *Trichoderma viridae*

First and final count germination (%)

The first and final count germination varied significantly among vigour levels, biological treatments and the interactions between V x B, T x B. Among the vigour levels, higher first and final counts germination (84.94 and 89.83%) was indicated in V_1 and it was lower (68.69 and 74.17%) in V_2, respectively. Among the biological treatments, higher first and final counts germination (84.67 and 87.42%) was registered in B_5 which was statistically on par with B_2 (83.33 and 85.58%), B_3 (81.67 and 84.67%) and it was lower in B_1 (59.25 and 73.50%). The findings of the study are in compliance with Harman and Taylor (1988) [9] who also opined that, priming of cucumber seeds with *Trichoderma harzianum* gave greater seedling emergence, rather than Thiram fungicide. Among V x B interactions, V_1B_2 registered higher (93.50%) final count germination which was also on par with V_1B_5 (92.50%), V_1B_3 (91.33%), V_1B_6 (91.33%) and it was lower (57.33%) in V_2B_1. Among T x B interactions, T_1B_2 depicted higher (89.34%) final count germination that was on par with T_1B_5 (89.33%), T_2B_3 (86%), T_2B_5 (85.50%) and T_2B_6 (84.67%) but it was lowest (73.33%) in T_1B_1, followed by T_2B_1 (73.67%).

Mean Germination Time (MGT) and speed of germination (BRI)

The MGT measured in days, also differed significantly due to vigour levels, temperatures, biological agents and the interactions of V x B and T x B. Among the vigour levels, lower MGT value (1.65 days) was recorded in V_1 and it was significantly higher (2.39 days) in V_2. Among temperatures, T_1 recorded lower MGT (1.96 days) and it was higher (2.09 days) in T_2. Among biological agents, lower MGT (1.63 days) was registered in B_2 which was statistically on par with B_3 and B_5 (1.77 days) and it was higher in B_1 (2.89 days). These findings were in accordance with the results of Amanda *et al*. (2009) [2] who reported that priming improved emergence and its time significantly in both carrot seed and C. *rosea* cv.IK726. Among T x B interactions, lower MGT (1.57 days) was observed in T_1B_5, which was statistically on par with T_1B_2 (1.63 days), T_2B_2 (1.63 days), T_2B_3 (1.66 days) and it was higher in T_1B_1 (2.81 days), followed by T_2B_1 (2.98 days). Among V x B interactions, V_1B_2 had registered lower MGT (1.26 days) and it was higher (3.26 days) in V_2B_1.

The BRI estimated to indicate the speed of germination demonstrated significant variations among the vigour levels, temperatures, biological agents and the interactions of V x B. Among the vigour levels, higher BRI (0.533) was noticed in V_1 and it was lower (0.490) in V_2. Among temperatures, higher BRI (0.515) was recorded in T_1 and it was lower (0.509) in T_2. Among biological agents, higher BRI (0.532) was observed in B_2 which was statistically on par with B_5 (0.526), but it was lower in B_1 (0.468). Among V x B interactions, V_1B_2 registered higher BRI (0.553) which was statistically on par with V_1B_5 (0.542), V_1B_3 (0.541) and it was lower (0.436) in V_2B_1. Further, BRI did not influenced by the interactions V x T, T x B and V x T x B.

Mean seedling length (cm) and mean seedling dry weight (mg)

The MSL was also differed significantly, among the vigour levels, it was higher (28.48 cm) in V_1 and lower in V_2 (25.11 cm). Among temperatures, higher MSL (27 cm) was recorded in T_1 and it was lower (26.60 cm) in T_2. Among the biological agents, higher MSL (30.38 cm) was registered in B_5 which was statistically on par with and B_2 (29.27 cm) and it was lower in B_1 (24.00 cm). The mean seedling dry weight (MSDW) showed significant differences among vigour levels, temperatures, biological agents and the interactions between V x T and V x T x B. Among vigour levels, higher MSDW (9.97 mg) was indicated in V_1 and it was lower (8.80 mg) in V_2. Among temperatures, higher MSDW (9.65 mg) was recorded in T_1 and it was lower (9.13 mg) in T_2. Among biological agents, higher MSDW (10.70 mg) was registered in B_2 which was statistically on par with B_5 (10.47 mg) and it was significantly lower in B_1 (6.91 mg).

Seedling Vigour index-I (SVI-I) and Seedling Vigour index-II (SVI-II)

Both SVI-I and SVI- II differed significantly due to vigour levels, it was higher (2562 and 899) in V_1 and lowest recorded in V_2 (1866 and 661), respectively. Among biological agents, higher SVI-I and II (2652 and 915) was registered in B_5 which was statistically on par with B_2 (2515 and 921) and it was significantly lower in B_1 (1755 and 519).

Conclusion

The low vigour seeds have recorded 28.33 per cent increase in the final count germination in contrast to 2.22 per cent increase in high vigour seeds due to biopriming, in comparison with unprimed seeds. Therefore, the best priming temperature is 25± 1^0C (T_1) and the best performed biological agents are cowdung slurry followed by PSB, Vermiwash, *Tricoderma viridae* and *Azospirillum* in the order of performance. The study also suggested that it is worthwhile to use cow dung slurry in conjunction with PSB as a common biopriming treatment to achieve higher, rapid and uniform germination in cucumber. These standardized biopriming protocols could be used for priming cucumber seeds for the production of healthy and elite seedlings.

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