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Impact of Seed Priming with Ag-Nanoparticle and GA_3 on Germination and Vigour in Green gram

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A B S T R A C T

Green gram (*Vigna radiata* L.) is one of the important pulse crops in India. It is widely cultivated throughout India in three different seasons. Eight genotypes of green gram viz, Pusa Vishal, PM-11-9, IPM-2-3, Meha (IPM 99-125), Samrat, IPM-512-1, TMB-37, SML-1822 were primed with GA_3 and Ag-nanoparticle for six hours. The laboratory experiment was done in seed testing laboratory, BCKV, West Bengal during 2019 & 2020. Germination percentage and vigour were observed to determine the change of seed quality after priming with Ag-Nanoparticle and GA_3. While considering genotypes over treatments, significantly highest germination percentage was observed i.e. 93.41 and 93.86 during 2019 and 2020 respectively in G_6 (IPM-512-1). The highest vigour index 1,899.182 and 1,897.412 were observed for G_1 (Pusa Vishal) among the genotypes over treatments, during 2019 and 2020 respectively. The treatment over genotypes, T_2 (Ag-Nanoparticle @ 20 ppm) was significantly higher than other treatments of germination percentage for both the year. Regarding treatment over the genotypes the maximum vigour index was observed 1,755.024 and 1,770.908 respectively in T_2 (Ag-Nanoparticle @ 20 ppm) for both the years. So, Ag-Nanoparticle was proved to be the best treatment among the other treatments and Pusa Vishal was the best among the other genotypes.

Introduction

Pulse crops play an important role in Indian agriculture and India is the largest producer and consumer of pulses in the world. Among pulses, green gram (*Vigna radiata* L.), having chromosome number 2n= 24, is widely cultivated in three different seasons in India i.e., pre-kharif, kharif and rabi. According to the twelfth five year plan (2012-15), the total area covered under moong in India is 30.41 lakh hectares with a total production of 14.24 lakh tonnes. The total area in West Bengal under green gram cultivation is 0.21 lakh ha, production 0.18 lakh tonnes, and yield 839 kg ha^{-1}. (Pulses in India: Retrospect and Prospects, 2016). Besides having easily digestible protein (20.0 to 28.4%) and high amount of amino acids (800.2 mg g^{-1}) (Yi-Shen *et al.*, 2018), it has other biochemical compositions like 3.3% fat, 5.9% fibre, 51.2% carbohydrate, 3.4% minerals, 0.3% vitamins and 10.2% moisture (USDA Nutrient Database, 2015). Main foundations for good

stand establishment of any crop are higher germination and vigour of the seedlings. Seed priming is of the techniques used to get higher germination and vigour. It is basically pre-sowing seed treatment in which the seeds are hydrated and dehydrated, which modifies physiological and biochemical properties of seed (Basu, 1976). The seed priming advances germination metabolism, enhances antioxidant activities and improves repair process. It is well accepted fact that priming improves germination, reduces seedling emergence time and improves stand establishment (Nawaz *et al.,* 2013). Seed priming can be of various types but here hydro priming and chemical priming was done to enhance the germination and vigour. Engineered nanomaterials like Silver nanoparticles (AgNPs) have been implicated nowadays to enhance seed germination, plant growth, and improvement of photosynthetic quantum efficiency and as antimicrobial agents to manage plant diseases (Almutairi and Alharbi, 2015). Seeds treated with synthesized AgNPs showed better germination (Parveen and Rao, 2015). Gibberellic acid (GA_3) is known to be concerned in the regulation of plant responses to the external environment (Chakrabarti and Mukherji, 2003), and application of Gibberellic Acid (GA_3) has been reported to increase germination percentage and seedling growth of crop plants under salt stress (Tsegay and Andargie, 2018, Biswas *et al.*, 2020a). GA_3 was found to influence the spikelet fertility and seed yield significantly (Biswas *et al.*, 2020b). The influence of GA_3 has been found to enhance seed yield plant^{-1}and all the seed yield attribute characters (Ray and Bordolui, 2020).

Objective of this study was to assess the response of those genotypes towards seed priming with chemicals viz., GA_3 and Ag-nanoparticle for quality seed production.

Materials and Methods

Previous season greengram seeds of the eight genotypes viz, Pusa Vishal, PM-11-9, IPM-2-3, Meha (IPM 99-125), Samrat, IPM-512-1, TMB-37, SML-1822 were primed with GA_3 and Ag-nanoparticle for six hours along with soaking in distilled water as control for the same period for making comparison of the effects of seed priming. After standardization, the dose of GA_3 @ 50 ppm and Ag-nanoparticle @ 20 ppm was selected for the research work. The genotypes were collected from AICRP on MULLaRP, BCKV. The laboratory experiment was done in seed testing laboratory, BCKV, West Bengal during 2019 & 2020. The different seed quality parameters such as root length, shoot length, seedling dry weight and fresh weight, germination percentage and vigour index were recorded. Germination test was carried out using glass plate and petri-plate method (ISTA, 1985) and calculated as Germination (%) = No. of normal seedlings germinated × 100/ Total no. of seeds placed for germination. Vigour Index was also calculated by Abdul-Baki and Anderson (1973) as Vigour index = Germination (%) × Seedling length (cm).

Root length (cm)

During 2019, significantly highest root length (8.414 cm) was observed for G_7 (TMB-37) followed by G_1 (Pusa Vishal) when the average was made over the treatments, while shortest root length (3.581 cm) was recognized for G_2 (PM-11-9) preceded by G_8 (SML-1822) (Table-1.a). In case of treatment over genotypes, T_2 (Ag-Nanoparticle @ 20 ppm) was significantly superior to that of 50 ppm GA_3 and control for the exhibition of root length. While considering the interaction between treatments and genotypes, a significantly maximum root length (8.730 cm) was recorded for G_7 (TMB-37) followed by

G_1 (Pusa Vishal) after application of 20 ppm Ag-Nanoparticle, and shortest root length (3.120 cm) was recorded for G_2 (PM-11-9) when primed with distilled water preceded by the same genotype when treated with 50 ppm of GA_3.

Similar to the first-year when the average was made over the treatments, root length of G_7 (TMB-37) was also found to be maximum (8.627cm) followed by that of G_1 (Pusa Vishal) during 2020 (Table-1.b). It was observed that G_2 (PM-11-9) produced the shortest roots of average 3.698 cm length preceded by G_8 (SML-1822). Influence of T_2 (Ag-Nanoparticle @ 20 ppm) over all genotypes was significantly superior to that of 50 ppm GA_3 and control for the exhibition of root length. While considering the interaction between treatments and genotypes, a significantly maximum root length (8.983 cm) was recorded for G_7 (TMB-37) followed by G_1 (Pusa Vishal) after application of 20 ppm Ag-Nanoparticle. But shortest root length i.e 3.203 cm was recorded for G_2 (PM-11-9) when primed with distilled water preceded by the same genotype when treated with 50 ppm of GA_3.

If ranking was made amongst the genotypes about its root length over treatments, it could be noticed as G_7> G_1> G_3> G_5> G_6> G_4> G_8> G_2 for the first year and G_7> G_1> G_3> G_6> G_4> G_5> G_8> G_2 for the second year.

Shoot Length (cm)

When the average was made over the treatments, the highest shoot length 12.480 cm and 12.163 cm respectively was observed significantly for G_1 (Pusa Vishal) followed by G_3 (IPM-2-3) during 2019 and 2020. The shortest shoot length (9.363 cm) was recorded for G_6 (IPM-512-1) preceded by G_2 (PM-11-9) for first-year (Table-2.a) but in second year shortest shoot length (9.424 cm) was recorded for G_6 (IPM-512-1) preceded by G_5 (Samrat) (Table-2.b). The influence of T_2 (Ag-Nanoparticle @ 20 ppm) was significantly superior (11.406 cm for 1st year and 11.352 cm for 2nd year) to that of 50 ppm GA_3 and control for the exhibition of shoot length when the average was made over the genotypes. While considering the interaction between treatments and genotypes, significantly maximum shoot length (13.557 cm for 1st year and 13.213 cm for 2nd year) was recorded for G_1 (Pusa Vishal) followed by G_3 (IPM-2-3) after application of 20 ppm Ag-Nanoparticle and shortest shoot length (8.850 cm for 1st year and 8.623 cm for 2nd year) was recorded for G_6 (IPM-512-1) when primed with distilled water preceded by the same genotype when treated with 50 ppm of GA_3.

Ranking amongst the genotypes about its shoot length over treatments for the first year was, G_1> G_3> G_7> G_5> G_8> G_4> G_2> G_6 and for the second year was, G_1> G_3> G_7> G_4> G_8> G_2> G_5> G_6.

Fresh weight (g)

Among the genotypes over treatments, the highest fresh weight i.e 2.210 g was noted in G_1 (Pusa Vishal) followed by G_2 (PM-11-9), while it was minimum (1.530 g) in G_8 (SML-1822) preceded by G_4 (Meha) during 2019 (Table-3.a). In case of treatment over genotypes, maximum fresh weight was observed 2.040 g and 2.039 g respectively in T_2 (Ag-Nanoparticle @ 20 ppm) during 2019 and 2020. While considering the interaction between treatments and genotypes, maximum fresh weight (2.370 g) was obtained for G_1 (Pusa Vishal) followed by G_2 (PM-11-9) while minimum fresh weight (1.320 g) was obtained for G_4 (Meha) preceded by G_8 (SML-1822) for the first year (Table-3.a) when primed with distilled water.

The average fresh weight of genotypes over treatments was significantly highest in the case of G_1 (Pusa Vishal) i.e 2.201g followed by G_2 (PM-11-9) during 2020 and alike previous year, minimum fresh weight (1.542 g) was observed in G_8 (SML-1822) preceded by G_4 (Meha). In case of interaction between treatments and genotypes, maximum fresh weight (2.313 g) was obtained for G_1 (Pusa Vishal) followed by G_3 (IPM-2-3) while minimum fresh weight (1.360 g) was obtained for G_8 (SML-1822) preceded by G_4 (Meha) when primed with distilled water in second year (Table-3b).

G_1> G_2> G_3> G_5> G_7> G_6> G_4> G_8 was the ranking amongst the genotypes about its fresh weight over treatments for the both the years.

Table.1.a Mean value of root length of different green gram genotypes during 2019

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	7.810	3.120	7.163	5.817	5.763	6.020	8.203	4.170	6.008
T_1	7.990	3.590	7.247	5.770	6.107	6.217	8.310	4.383	6.202
T_2	8.400	4.033	8.180	6.553	6.993	6.480	8.730	5.143	6.814
Mean G	8.067	3.581	7.530	6.047	6.288	6.239	8.414	4.566	
	T	**G**	**TXG**						
SEm(±)	**0.003**	**0.004**	**0.008**						
LSD	**0.008**	**0.013**	**0.022**						

Table.1b Mean value of root length of different green gram genotypes during 2020

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	8.063	3.203	7.060	5.420	5.620	5.897	8.490	4.023	5.972
T_1	8.220	3.410	7.577	6.023	5.903	5.983	8.407	4.680	6.275
T_2	8.533	4.480	8.243	7.043	6.420	6.617	8.983	5.490	6.976
Mean G	8.272	3.698	7.627	6.162	5.981	6.166	8.627	4.731	
	T	**G**	**TXG**						
SEm(±)	**0.004**	**0.007**	**0.012**						
LSD	**0.012**	**0.019**	**0.033**						

T= Treatments, T_0= Control, T_1= GA_3, T_2= Ag-Nanoparticle
G= Genotypes, G_1= Pusa Vishal, G_2= PM-11-9, G_3= IPM-2-3, G_4= Meha (IPM 99-125), G_5= Samrat, G_6= IPM-512-1, G_7= TMB-37, G_8= SML-1822

Table.2.a Mean value of shoot length of different green gram genotypes during 2019

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	11.340	9.397	10.410	10.020	10.263	8.850	10.697	10.400	10.172
T_1	12.543	10.050	12.507	10.250	10.593	9.170	11.030	10.410	10.819
T_2	13.557	10.303	13.373	10.933	10.883	10.070	11.330	10.800	11.406
Mean G	12.480	9.917	12.097	10.401	10.580	9.363	11.019	10.537	
	T	**G**	**TXG**						
SEm(±)	**0.003**	**0.004**	**0.008**						
LSD	**0.008**	**0.013**	**0.022**						

Table.2.b Mean value of shoot length of different green gram genotypes during 2020

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	11.140	9.797	10.847	10.123	10.147	8.623	10.517	10.283	10.185
T_1	12.137	10.380	12.040	10.670	10.240	9.447	11.427	10.583	10.865
T_2	13.213	10.753	13.040	11.130	10.440	10.203	11.587	10.450	11.352
Mean G	12.163	10.310	11.976	10.641	10.276	9.424	11.177	10.439	
	T	G	TXG						
SEm(±)	0.003	0.005	0.008						
LSD	0.008	0.013	0.022						

T= Treatments, T_0= Control, T_1= GA_3, T_2= Ag-Nanoparticle
G= Genotypes, G_1= Pusa Vishal, G_2= PM-11-9, G_3= IPM-2-3, G_4= Meha (IPM 99-125), G_5= Samrat, G_6= IPM-512-1, G_7= TMB-37, G_8= SML-1822

Table.3.a Mean value of fresh weight (g) of different green gram genotypes during 2019

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	2.040	1.860	1.700	1.320	1.800	1.510	1.470	1.380	1.635
T_1	2.220	1.980	2.010	1.643	1.910	1.600	1.667	1.500	1.816
T_2	2.370	2.270	2.200	1.780	2.037	1.960	1.990	1.710	2.040
Mean G	2.210	2.037	1.970	1.581	1.916	1.690	1.709	1.530	
	T	G	TXG						
SEm(±)	0.002	0.004	0.007						
LSD	0.007	0.011	0.019						

Table.3.b Mean value of fresh weight (g) of different green gram genotypes during 2020

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	2.080	1.853	1.637	1.390	1.840	1.440	1.480	1.360	1.635
T_1	2.210	1.930	1.947	1.630	1.887	1.563	1.730	1.520	1.802
T_2	2.313	2.180	2.250	1.820	1.963	1.987	2.050	1.747	2.039
Mean G	2.201	1.988	1.944	1.613	1.897	1.663	1.753	1.542	
	T	G	TXG						
SEm(±)	0.002	0.004	0.007						
LSD	0.007	0.011	0.019						

T= Treatments, T_0= Control, T_1= GA_3, T_2= Ag-Nanoparticle
G= Genotypes, G_1= Pusa Vishal, G_2= PM-11-9, G_3= IPM-2-3, G_4= Meha (IPM 99-125), G_5= Samrat, G_6= IPM-512-1, G_7= TMB-37, G_8= SML-1822

Table.4.a Mean value of dry weight (g) of different green gram genotypes during 2019

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	0.160	0.120	0.160	0.150	0.160	0.190	0.140	0.140	0.153
T_1	0.190	0.150	0.210	0.140	0.200	0.200	0.170	0.150	0.176
T_2	0.233	0.190	0.220	0.170	0.237	0.180	0.200	0.170	0.200
Mean G	0.194	0.153	0.197	0.153	0.199	0.190	0.170	0.153	
	T	G	TXG						
SEm(±)	0.002	0.004	0.006						
LSD	0.006	0.010	0.017						

Table.4.b Mean value of dry weight (g) of different green gram genotypes during 2020

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	0.170	0.150	0.140	0.130	0.160	0.160	0.150	0.140	0.150
T_1	0.180	0.170	0.230	0.160	0.210	0.230	0.160	0.150	0.186
T_2	0.250	0.190	0.200	0.180	0.260	0.200	0.180	0.163	0.203
Mean G	0.200	0.170	0.190	0.157	0.210	0.197	0.163	0.151	
	T	**G**	**TXG**						
SEm(±)	**0.002**	**0.003**	**0.006**						
LSD	**0.006**	**0.009**	**0.016**						

T= Treatments, T_0= Control, T_1= GA_3, T_2= Ag-Nanoparticle

G= Genotypes, G_1= Pusa Vishal, G_2= PM-11-9, G_3= IPM-2-3, G_4= Meha (IPM 99-125), G_5= Samrat, G_6= IPM-512-1, G_7= TMB-37, G_8= SML-1822

Table.5.a Mean value of germination percentage of different green gram genotypes during 2019

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	87.41 (69.197)	90 (71.540)	90.33 (71.863)	85.75 (67.801)	88.91 (70.530)	89.5 (71.072)	90.33 (71.861)	90.41 (71.947)	89.08 (70.726)
T_1	92.58 (74.170)	93.33 (75.022)	93.5 (75.211)	89.83 (71.380)	93.66 (75.405)	94 (75.793)	91.58 (73.108)	91.25 (72.775)	92.46 (74.108)
T_2	96.67 (79.470)	96.83 (79.785)	95.75 (78.113)	94.33 (76.207)	97.08 (80.149)	96.75 (79.602)	97.08 (80.159)	96.08 (78.563)	96.32 (79.006)
Mean G	92.22 (74.279)	93.38 (75.449)	93.19 (75.062)	89.97 (71.796)	93.22 (75.361)	93.41 (75.489)	93 (75.043)	92.58 (74.428)	
	T	**G**	**TXG**						
SEm(±)	**0.150**	**0.245**	**0.424**						
LSD	**0.428**	**0.698**	**1.209**						

Table.5.b Mean value of germination percentage of different green gram genotypes during 2020

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	87.67 (69.414)	90.33 (71.861)	89.67 (71.222)	86 (68.003)	89 (70.607)	89.83 (71.386)	90.83 (72.350)	90.67 (72.195)	89.5 70.880
T_1	93.16 (74.820)	92.91 (74.549)	93.67 (75.412)	90.41 (71.949)	94.08 (75.900)	94.83 (76.837)	91.5 (73.021)	91.08 (72.601)	92.70 74.386
T_2	97.17 (80.354)	97.17 (80.305)	96.58 (79.346)	95.08 (77.164)	96.91 (79.867)	96.91 (79.867)	97.17 (80.305)	95.83 (78.212)	96.60 79.428
Mean G	92.66 (74.862)	93.47 (75.572)	93.30 (75.327)	90.5 (72.372)	93.33 (75.458)	93.86 (76.030)	93.16 (75.225)	92.52 (74.336)	
	T	**G**	**TXG**						
SEm(±)	**0.150**	**0.245**	**0.424**						
LSD	**0.427**	**0.698**	**1.209**						

T= Treatments, T_0= Control, T_1= GA_3, T_2= Ag-Nanoparticle

G= Genotypes, G_1= Pusa Vishal, G_2= PM-11-9, G_3= IPM-2-3, G_4= Meha (IPM 99-125), G_5= Samrat, G_6= IPM-512-1, G_7= TMB-37, G_8= SML-1822

Table.6.a Mean value of vigour index of different green gram genotypes during 2019

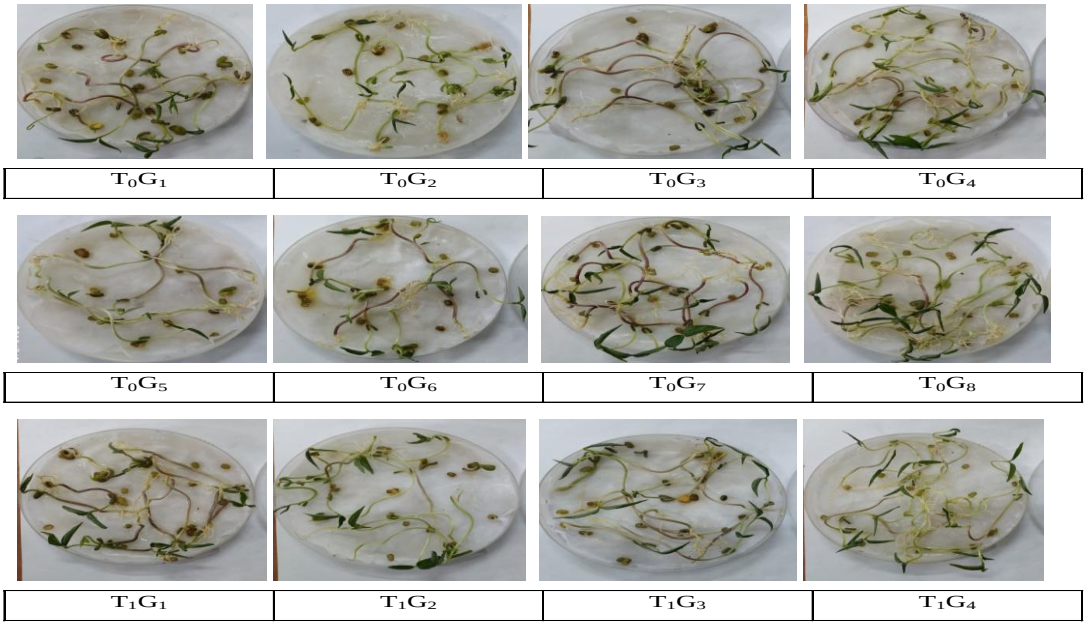
	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	1,674.027	1,126.502	1,587.456	1,358.007	1,425.034	1,330.863	1,707.295	1,317.376	1,440.820
T_1	1,901.037	1,273.068	1,846.931	1,439.133	1,564.232	1,446.348	1,771.224	1,349.889	1,573.983
T_2	2,122.483	1,388.277	2,063.725	1,649.571	1,735.533	1,601.217	1,947.495	1,531.891	1,755.024
Mean G	1,899.182	1,262.616	1,832.704	1,482.237	1,574.933	1,459.476	1,808.671	1,399.719	
	T	**G**	**TXG**						
LSD	**6.163**	**10.065**	**17.433**						
SEm(±)	**2.161**	**3.529**	**6.112**						

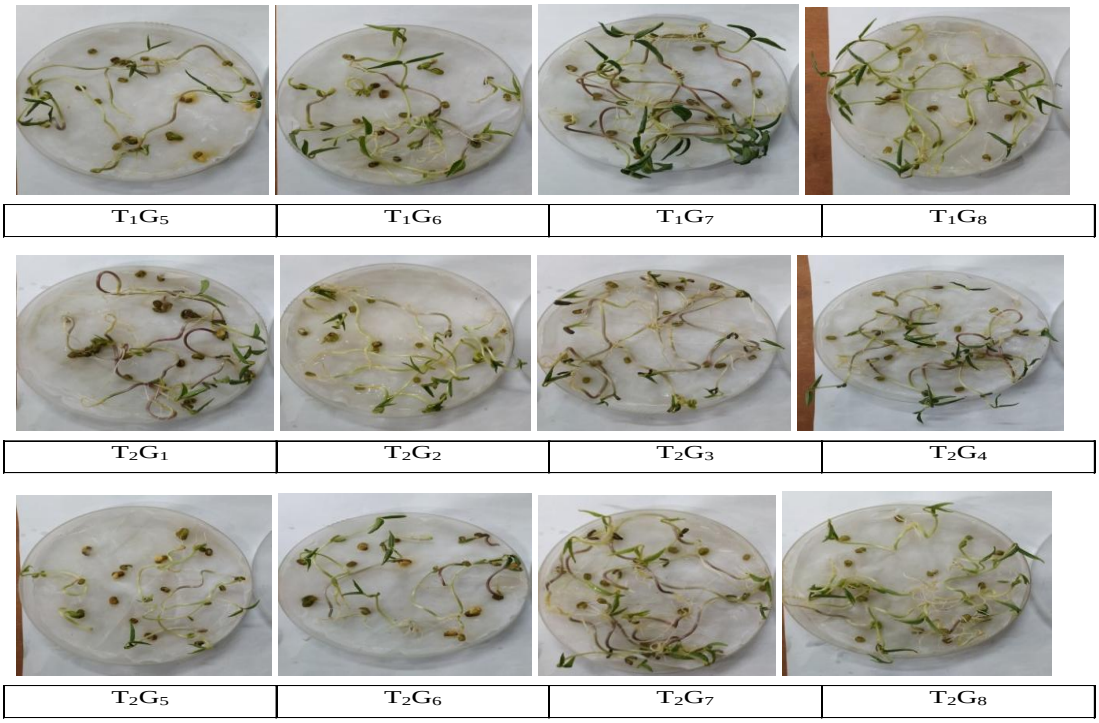
Table.6.b Mean value of vigour index of different green gram genotypes during 2020

	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	Mean T
T_0	1,697.225	1,192.998	1,605.619	1,435.624	1,428.454	1,304.365	1,737.040	1,297.155	1,462.310
T_1	1,881.972	1,262.111	1,837.440	1,405.365	1,492.157	1,463.273	1,822.371	1,390.240	1,569.366
T_2	2,113.040	1,480.166	2,055.616	1,727.977	1,634.012	1,630.138	1,998.726	1,527.588	1,770.908
Mean G	1,897.412	1,311.758	1,832.892	1,522.989	1,518.208	1,465.926	1,852.712	1,404.995	
	T	**G**	**TXG**						
LSD	**5.876**	**9.596**	**16.621**						
SEm(±)	**2.060**	**3.364**	**5.827**						

T= Treatments, T_0= Control, T_1= GA_3, T_2= Ag-Nanoparticle
G= Genotypes, G_1= Pusa Vishal, G_2= PM-11-9, G_3= IPM-2-3, G_4= Meha (IPM 99-125), G_5= Samrat, G_6= IPM-512-1, G_7= TMB-37, G_8= SML-1822

Fig.1 Germination and vigour test of primed seed of different green gram genotypes





Dry weight (g)

While considering the interaction between treatments and genotypes in first year, highest dry weight (0.237 g) was found in G_5 (Samrat) followed by G_1 (Pusa Vishal) when treated with T_2 i.e. Ag-Nanoparticle @ 20 ppm (Table-4.a). Similar type of observation was recorded in second year also where highest dry weight (0.260 g) was found in G_5 (Samrat) followed by G_1 (Pusa Vishal) (Table-4.b). In the first year lowest dry weight (0.120 g) was observed for G_2 (PM-11-9) when primed with distilled water preceded by G_7 (TMB-37) and G_8 (SML-1822) when primed with distilled water and G_4 (Meha) when treated with 50 ppm GA_3. But in case of the second year, lowest dry weight (0.130 g) was obtained in G_4 (Meha) preceded by G_3 (IPM-2-3) and G_8 (SML-1822) when primed with distilled water. During both the years when treatment over genotypes was considered, influence of T_2 (Ag-Nanoparticle @ 20 ppm) was significantly superior (0.200 g for 1st year and 0.203g for 2nd year) to that of 50 ppm GA_3 and control for the exhibition of dry weight. In case of genotype over treatments, highest dry weight (0.199 g) was obtained for G_5 (Samrat) followed by G_3 (IPM-2-3) but lowest dry weight (0.153 g) was observed in G_2 (PM-11-9), G_4 (Meha) and G_8 (SML-1822) preceded by G_7 (TMB-37) during first year. In second year, the highest dry weight 0.210 g was recorded in G_5 (Samrat) followed by G_1 (Pusa Vishal) but lowest dry weight (0.151 g) was observed in G_8 (SML-1822) preceded by G_4 (Meha).

If ranking was made amongst the genotypes about its dry weight over treatments, it could be noted for the first year- $G_5 > G_3 > G_1 > G_6 > G_7 > G_2 = G_4 = G_8$ and for the second year- $G_5 > G_1 > G_6 > G_3 > G_2 > G_7 > G_4 > G_8$.

Germination percentage

During first year significantly highest germination percentage (93.41) was observed in G_6 (IPM-512-1) followed by G_2 (PM-11-9) when the average was made over the

treatments, while the lowest germination percentage (89.97) was recognized for G_4 (Meha) preceded by G_1 (Pusa Vishal) (Table-5.a). The treatment over genotypes, T_2 (Ag-Nanoparticle @ 20 ppm) was significantly higher than that of 50 ppm GA_3 and control for the exhibition of germination percentage for both the years. While considering the interaction between treatments and genotypes, significantly maximum germination percentage (97.08) was recorded for G_7 (TMB-37) and G_5 (Samrat) followed by G_2 (PM-11-9) after application of 20 ppm Ag-Nanoparticle, and the lowest germination percentage (85.75) was recorded for G_4 (PM-11-9) preceded by G_1 (Pusa Vishal) when primed with distilled water (Fig. 1).

Similar to the first year genotypes over treatments, germination percentage of G_6 (IPM-512-1) was also found to be maximum (93.86) followed by that of G_2 (PM-11-9) during 2020 (Table-5.b). The lowest germination percentage (90.5) was observed G_4 (Meha) was preceded by G_8 (SML-1822). While considering the interaction between genotypes and treatments, a significantly maximum germination percentage (97.17) was recorded for G_1 (Pusa Vishal), G_2 (PM-11-9) and G_7 (TMB-37) followed by G_5 (Samrat) and G_6 (IPM-512-1) after application of 20 ppm Ag-Nanoparticle while lowest germination percentage (86) was recorded for G_4 (Meha) preceded by G_1 (Pusa Vishal) when primed with distilled water.

Ranking of germination percentage amongst the genotypes over treatments noticed as G_6> G_2> G_5> G_3> G_7> G_8> G_1 > G_4 for the first year and G_6> G_2> G_5> G_3> G_7> G_1> G_8> G_4 for the second year.

Vigour index

Among the genotypes over treatments, the highest vigour index (1,899.182) was noted for G_1 (Pusa Vishal) followed by G_3 (IPM-2-3), while it was minimum (1,262.616) for G_2 (PM-11-9) preceded by G_8 (SML-1822) during 2019 (Table 6.a). The treatment over the genotypes, maximum vigour index was observed for T_2 (Ag-Nanoparticle @ 20 ppm) (1,755.024 and 1,770.908 respectively) for both the years. In case of considering the interaction between treatments and genotypes, the significantly highest vigour index (2,122.483) was obtained for G_1 (Pusa Vishal) followed by G_3 (IPM-2-3) after application of 20 ppm Ag-Nanoparticle, while minimum vigour index (1,126.502) was obtained for G_2 (PM-11-9) when primed with distilled water preceded by the same genotype when treated with 50 ppm of GA_3.

The genotype over treatments vigour index was significantly higher in the case of G_1 (Pusa Vishal) i.e 1,897.412 followed by G_7 (TMB-37) during 2020 and similar to first year, lowest vigour index (1,311.758) was observed in G_2 (PM-11-9) preceded by G_8 (SML-1822) (Table 6.b). While considering the interaction between treatments and genotypes, the highest vigour index (2,113.040) was obtained for G_1 (Pusa Vishal) followed by G_3 (IPM-2-3) after application of 20 ppm Ag-Nanoparticle, while the lowest vigour index (1,192.998) was obtained for G_2 (PM-11-9) when primed with distilled water preceded by the same genotype when treated with 50 ppm of GA_3.

When the ranking was made about its vigour index amongst the genotypes over treatments, it could be noted as G_1> G_3> G_7> G_5> G_4> G_6> G_8> G_2 for the first year and G_1> G_7> G_3> G_4> G_5> G_6> G_8> G_2 for the second year.

It can be concluded that Ag-Nanoparticle @ 20 ppm was the best treatment among the other treatments like GA_3 and control as germination and vigour index was observed maximum during both the years. Significantly

highest germination percentage (93.41 and 93.86) was observed in G_6 (IPM-512-1) when average was made over the treatments in both the years which is near to G_1 (Pusa Vishal) i.e 92.22 and 92.66. In case of genotype over treatments, highest vigour index (1,899.182 and 1,897.412) was observed for G_1 (Pusa Vishal) in both the years. Among the genotypes Pusa Vishal had highest vigour and second highest in germination. So, Pusa Vishal was proved to be the best.

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