

# Standardization of the Appropriate Doses of GA<sub>3</sub> and Ag-Nanoparticle in Green Gram for Quality Seed Production

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**Abstract**— One of the most important pulse crops in India is green gram (*Vigna radiata* L.). Pre-sowing seed priming is a promising strategy to provide value-added solutions that influence the yield and quality of the seed. For selecting the appropriate doses of Ag-nanoparticle and GA<sub>3</sub>, three doses were taken for each chemical and eight genotypes of green gram were selected. The doses of Ag-nanoparticle were 10 ppm, 20 ppm and 50 ppm and for GA<sub>3</sub> 50 ppm, 100 ppm, 150 ppm. Eight genotypes of green gram were soaked with three doses each of GA<sub>3</sub> and Ag-nanoparticle solution for 6 hours. The laboratory experiment was conducted in seed testing laboratory, BCKV, West Bengal during 2019. Germination percentage and vigor were observed to determine the changes in seed quality after priming with different doses GA<sub>3</sub> and Ag-Nanoparticle. While considering treatments over genotypes for GA<sub>3</sub>, significantly highest germination percentage (99.16) and vigour index (2017.937) were observed when it was primed with 50 ppm GA<sub>3</sub>. In case of Ag-nanoparticle significantly highest germination percentage (99.31) and vigour index (2102.632) were recorded for 20 ppm, when the average was made over genotypes. So, Ag-Nanoparticle @ 20 ppm and GA<sub>3</sub> @ 50 ppm were proved to be appropriate dose in green gram for quality seed production.

**Keywords**— Green gram, Ag-Nanoparticle, GA<sub>3</sub>, Seed priming.

## I. INTRODUCTION

The mung bean (*Vigna radiata* L.) is a food legume mainly grown in South and South-East Asia commonly known as green gram is an economically important crop belonging to the family Fabaceae. The crop is known to be first originated and domesticated in India several thousand years ago and then spread to China and other parts of South-East Asia (Vavilov, 1926). This crop can be grown successfully in extreme environmental conditions like low rain fall, high temperatures, and poor soils with few economic inputs. Nair *et al.*, 2013 reported that mung bean seeds are a rich source of high quality protein (24%), carbohydrates (63%), iron (0.03-0.06 mg g<sup>-1</sup>) and zinc (0.02-0.04 mg g<sup>-1</sup>). Despite various good qualities of mungbean, the global average productivity is staggeringly low at 0.5 t ha<sup>-1</sup> which is far below than the estimated yield potential, i.e. 2.5-3.0 t ha<sup>-1</sup> of the crop (Nair *et al.*, 2019). India grows 65% (3.0 million ha) of total mungbean acreage and provides 54% (1.5 million tonnes) of the global production (AICRP on MULLaRP: [http://www.aicrpmullarp.res.in/crop\\_profile.html](http://www.aicrpmullarp.res.in/crop_profile.html)).

The growth in the human population has outpaced the production of pulses in the country which has led to gradual decrease in per capita pulse consumption. Seed priming prior to sowing is a promising strategy to provide value-added solutions that enhance the yield and quality potential of high-value crops. Priming instigates an increase in the activity of enzymes such as amylases, proteases, and lipases that break down macromolecules for growth and development of the embryo. Priming also reduces stress at the germination stage and ultimately results in higher rates of seedling emergence and successful seedling establishment. These biological consequences ultimately benefit farmers because it reduces the time, expense of re-seeding, additional irrigation, fertilization, and weed management on weak plants. Several chemicals including synthetic plant hormones have been used for seed priming. Plant hormones are vital members of the signal cascade complicated in the induction of plant stress responses. Moreover in recent years, nanotechnology has emerged as an advanced seed priming technology for smart agriculture. Important and unique aspects of nanoparticles, such as their surface to mass ratio, which is much greater than that of other particles and materials, allows them to efficiently increase catalysis, as well as to adsorb and deliver substances of interest. Nanoparticles derived from metals or their compounds have been evolved and utilized as carriers for biological systems. In this study, the effect of priming with a plant growth regulator (GA<sub>3</sub>) and silver nanoparticles on seed germination and early seedling growth has been demonstrated. Application of Gibberellic Acid (GA<sub>3</sub>)

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<sub>3</sub> was found to influence the spikelet fertility and seed yield significantly (Biswas *et al.*, 2020b). The influence of GA<sub>3</sub> has been found to enhance seed yield plant<sup>-1</sup> and all the seed yield attribute characters. (Ray and Bordolui, 2020). Consequently, nano-priming enhances the rate of emergence and subsequent growth, yield, and quality of the crop. Recent studies have reported that a plant's response to Ag-nanoparticles, enhancement or inhibition of growth, depends on the Ag-nanoparticle dosage. Exposure to specific concentrations of Ag-nanoparticles could enhance plant growth compared with non-exposed plants, whereas higher and lower concentrations could affect plant growth negatively. Objective of this study was to standardize the appropriate doses of Ag-nanoparticle and GA<sub>3</sub> for quality seed production of green gram.

## II. RESEARCH METHODS

For standardization the appropriate doses of Ag-nanoparticle and GA<sub>3</sub> in green gram, we selected three doses each of Ag-nanoparticle and GA<sub>3</sub> and eight genotypes of green gram. In case of Ag-nanoparticle the doses were 10 ppm, 20 ppm and 50 ppm and for GA<sub>3</sub> 50 ppm, 100 ppm, 150 ppm. Eight genotypes of green gram were Pusa Vishal (G<sub>1</sub>), PM-11-9 (G<sub>2</sub>), IPM-2-3 (G<sub>3</sub>), Meha (IPM 99-125) (G<sub>4</sub>), Samrat (G<sub>5</sub>), IPM-512-1 (G<sub>6</sub>), TMB-37 (G<sub>7</sub>), SML-1822 (G<sub>8</sub>), which were soaked with three doses each of GA<sub>3</sub> and Ag-nanoparticle solution separately for 6 hours to determine the best suitable dose each for GA<sub>3</sub> and Ag-nanoparticle. The laboratory experiment was conducted in Seed Testing Laboratory, BCKV, and West Bengal during 2019. The different seed quality parameters such as root length, shoot length, seedling dry weight, fresh weight, germination percentage and vigor index were recorded. Germination test was carried out using glassplate and petri-plate method (ISTA, 1985) and calculated as

$$\text{Germination (\%)} = \text{No. of normal seedlings germinated} \times 100 / \text{Total no. of seeds placed for germination.}$$

Root length and shoot length test was carried out by glassplate method. Vigor Index was also calculated by Abdul-Baki and Anderson (1973) as

$$\text{Vigor index} = \text{Germination (\%)} \times \text{Seedling length (cm)}.$$

## III. RESULTS AND DISCUSSIONS

### 3.1 Root Length (cm) of genotypes after priming with GA<sub>3</sub>

Significantly highest root lengths (13.038 cm) were observed for G<sub>5</sub> (Samrat) followed by G<sub>2</sub> (PM-11-9) when the average was made over the treatments, while shortest root lengths (6.953 cm) were recognized for G<sub>7</sub> (TMB-37) preceded by G<sub>1</sub> (Pusa Vishal). The influence of T<sub>1</sub> (50 ppm GA<sub>3</sub>) over all genotypes was significantly superior to that of 100 ppm and 150 ppm GA<sub>3</sub> for the exhibition of root length. While considering the interaction between treatments and genotypes, a significantly maximum root length (14.427 cm) was recorded for G<sub>5</sub> (Samrat) followed by G<sub>3</sub> (IPM-2-3) after application of 50 ppm GA<sub>3</sub>, and shortest root length (5.013 cm) was recorded for G<sub>7</sub> (TMB-37) preceded by G<sub>3</sub> (IPM-2-3) when treated with 150 ppm of GA<sub>3</sub>.

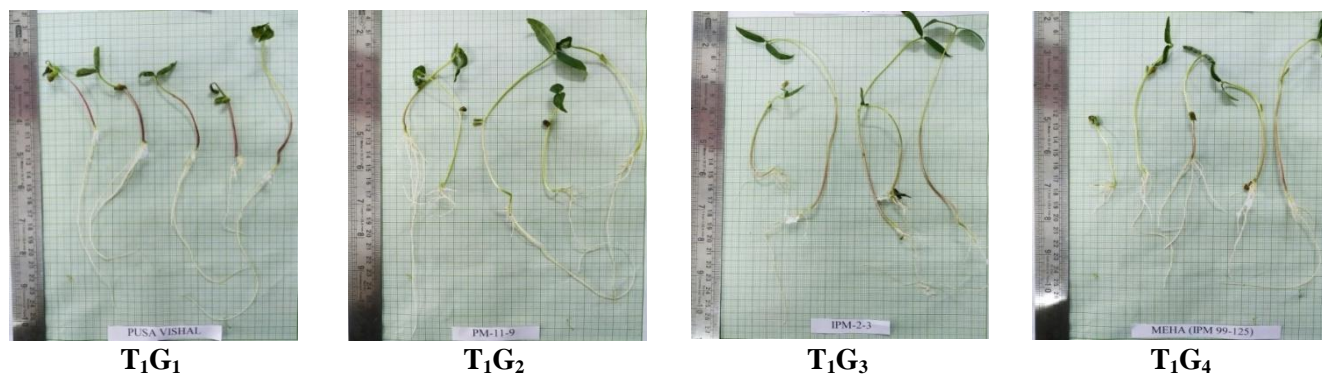
When the ranking is made amongst the genotypes over treatments about its root length, it could be noted as G<sub>5</sub> > G<sub>2</sub> > G<sub>3</sub> > G<sub>4</sub> = G<sub>6</sub> > G<sub>8</sub> > G<sub>1</sub> > G<sub>7</sub>.

**TABLE 1**  
**MEAN VALUE OF ROOT LENGTH OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF GA<sub>3</sub>**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	8.023	12.827	13.217	9.623	14.427	10.047	8.407	8.853	10.678
T <sub>2</sub>	7.210	8.820	6.650	6.247	12.863	6.630	7.440	6.623	7.810
T <sub>3</sub>	7.193	9.783	6.227	9.040	11.823	8.233	5.013	7.040	8.044
Mean G	7.476	10.477	8.698	8.303	13.038	8.303	6.953	7.506	
	T	G	TXG						
SEm(±)	0.005	0.008	0.014						
LSD	0.014	0.023	0.040						

T = GA<sub>3</sub>, T<sub>1</sub> = 50 ppm, T<sub>2</sub> = 100 ppm, T<sub>3</sub> = 150 ppm

G = Genotypes, G<sub>1</sub> = Pusa Vishal, G<sub>2</sub> = PM-11-9, G<sub>3</sub> = IPM-2-3, G<sub>4</sub> = Meha (IPM 99-125), G<sub>5</sub> = Samrat, G<sub>6</sub> = IPM-512-1, G<sub>7</sub> = TMB-37, G<sub>8</sub> = SML-1822.



**FIGURE 1: Images of germination and vigour test of green gram genotypes after priming with dose of 50 ppm GA<sub>3</sub> (T<sub>1</sub>).**

**3.2 Shoot Length (cm) of genotypes after priming with GA<sub>3</sub>**

Highest shoot lengths (9.896 cm) were observed for G<sub>1</sub> (Pusa Vishal) followed by G<sub>5</sub> (Samrat), while shortest shoot lengths (5.949 cm) were recognized for G<sub>3</sub> (IPM-2-3) preceded by G<sub>6</sub> (IPM-512-1) when the average was made over the treatments. The influence of T<sub>2</sub> i.e. 100 ppm and T<sub>3</sub> i.e. 150 ppm GA<sub>3</sub> was significantly inferior to that of T<sub>1</sub> (50 ppm GA<sub>3</sub>) for the exhibition of shoot length when the average was made over genotypes. A significantly maximum shoot length (12.627 cm) was recorded for G<sub>1</sub> (Pusa Vishal) followed by G<sub>2</sub> (PM-11-9) after application of 50 ppm GA<sub>3</sub>, and shortest shoot length (4.200 cm) was recorded for G<sub>3</sub> (IPM-2-3) preceded by G<sub>8</sub> (SML-1822) when treated with 150 ppm of GA<sub>3</sub> when the interaction between treatments and genotypes was considered.

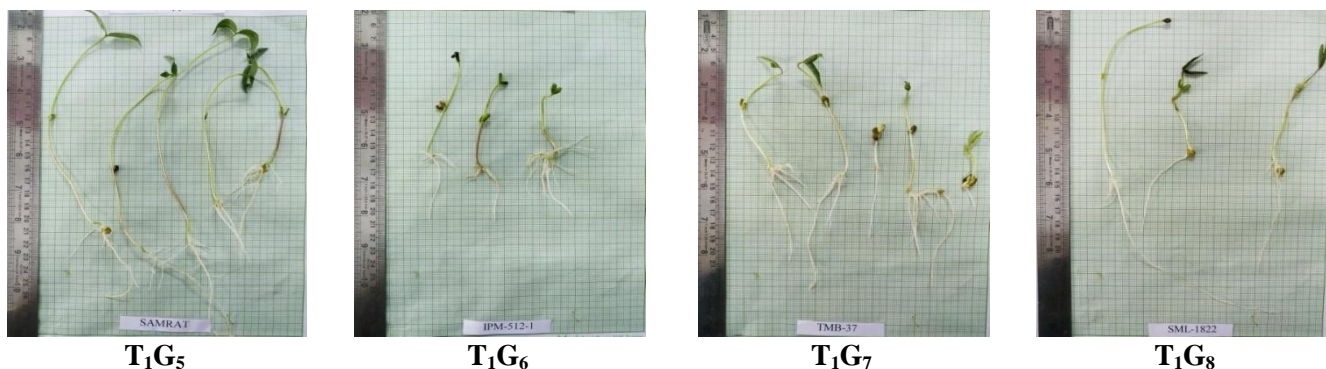
G<sub>1</sub>> G<sub>5</sub>> G<sub>2</sub>> G<sub>4</sub>> G<sub>8</sub>> G<sub>7</sub>> G<sub>6</sub>> G<sub>3</sub> is the ranking amongst the genotypes about its shoot length over treatments.

**TABLE 2  
MEAN VALUE OF SHOOT LENGTH OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF GA<sub>3</sub>**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	12.627	11.620	8.223	8.627	11.333	6.620	8.633	9.613	9.662
T <sub>2</sub>	8.623	6.840	5.423	5.430	10.627	4.860	7.423	7.230	7.057
T <sub>3</sub>	8.437	9.017	4.200	7.427	7.020	7.617	4.613	4.430	6.595
Mean G	9.896	9.159	5.949	7.161	9.660	6.366	6.890	7.091	
	T	G	TXG						
SEm(±)	0.008	0.012	0.022						
LSD	0.022	0.035	0.061						

T = GA<sub>3</sub>, T<sub>1</sub> = 50 ppm, T<sub>2</sub> = 100 ppm, T<sub>3</sub> = 150 ppm

G = Genotypes, G<sub>1</sub> = Pusa Vishal, G<sub>2</sub> = PM-11-9, G<sub>3</sub> = IPM-2-3, G<sub>4</sub> = Meha (IPM 99-125), G<sub>5</sub> = Samrat, G<sub>6</sub> = IPM-512-1, G<sub>7</sub> = TMB-37, G<sub>8</sub> = SML-1822.



**FIGURE 2: Images of germination and vigour test of green gram genotypes after priming with dose of 50 ppm GA<sub>3</sub>(T<sub>1</sub>).**

### 3.3 Fresh weight (g) of genotypes after priming with GA<sub>3</sub>

Significantly lowest fresh weight (0.631 g) were recognized for G<sub>2</sub> (PM-11-9) preceded by G<sub>8</sub> (SML-1822) while highest fresh weight (0.866 g) were observed for G<sub>6</sub> (IPM-512-1) followed by G<sub>4</sub> (Meha) when the average was made over the treatments. Influence of T<sub>1</sub> (50 ppm GA<sub>3</sub>) was significantly superior to that of 100 ppm and 150 ppm GA<sub>3</sub> for the exhibition of fresh weight when the average was made over genotypes. In case of the interaction between treatments and genotypes, a significantly maximum fresh weight (1.047 g) was recorded for G<sub>7</sub> (TMB-37) followed by G<sub>6</sub> (IPM-512-1) after application of 50 ppm GA<sub>3</sub>, and lowest fresh weight (0.257 g) was observed for G<sub>7</sub> (TMB-37) preceded by G<sub>3</sub> (IPM-2-3) when treated with 100 ppm of GA<sub>3</sub>.

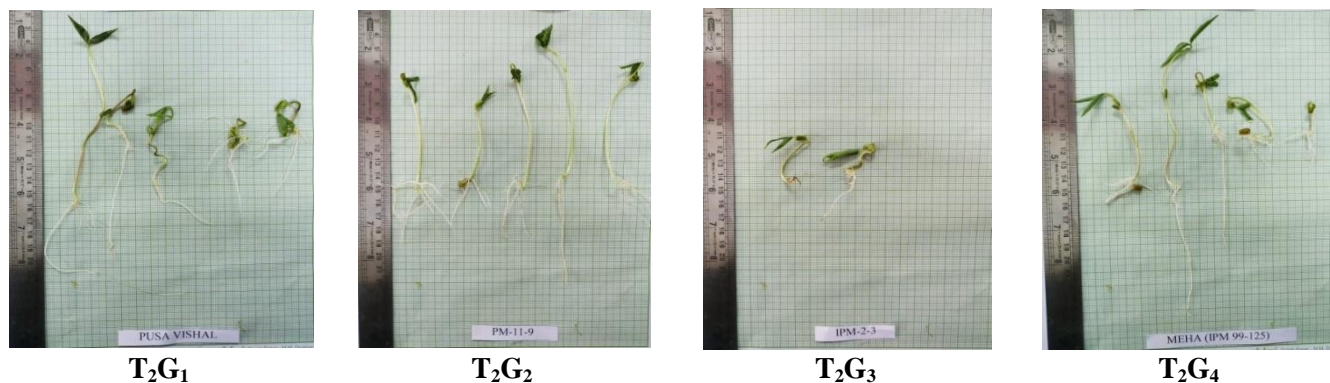
Ranking amongst the genotypes about its fresh weight over treatments is, G<sub>6</sub>> G<sub>4</sub>> G<sub>1</sub>> G<sub>7</sub>> G<sub>5</sub>> G<sub>3</sub>> G<sub>8</sub>> G<sub>2</sub>.

**TABLE 3**  
MEAN VALUE OF FRESH WEIGHT OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF GA<sub>3</sub>

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	0.987	0.437	0.863	0.923	0.863	1.010	1.047	0.837	0.871
T <sub>2</sub>	0.940	0.867	0.410	0.813	0.640	0.660	0.257	0.640	0.653
T <sub>3</sub>	0.557	0.590	0.823	0.820	0.647	0.927	0.970	0.613	0.743
Mean G	0.828	0.631	0.699	0.852	0.717	0.866	0.758	0.697	
	T	G	TXG						
SEm(±)	0.024	0.039	0.068						
LSD	0.069	0.112	0.195						

T= GA<sub>3</sub>, T<sub>1</sub>= 50 ppm, T<sub>2</sub>= 100 ppm, T<sub>3</sub>= 150 ppm

G= Genotypes, G<sub>1</sub>= Pusa Vishal, G<sub>2</sub>= PM-11-9, G<sub>3</sub>= IPM-2-3, G<sub>4</sub>= Meha (IPM 99-125), G<sub>5</sub>= Samrat, G<sub>6</sub>= IPM-512-1, G<sub>7</sub>= TMB-37, G<sub>8</sub>= SML-1822.



**FIGURE 3: Images of germination and vigour test of green gram genotypes after priming with dose of 100 ppm GA<sub>3</sub> (T<sub>2</sub>).**

### 3.4 Dry weight (g) of genotypes after priming with GA<sub>3</sub>

Significantly highest dry weight (0.108 g) were recorded for G<sub>2</sub> (PM-11-9) followed by G<sub>1</sub> (Pusa Vishal), while lowest dry weight (0.069 g) were recognized for G<sub>8</sub> (SML-1822) preceded by G<sub>3</sub> (IPM-2-3) when the average was made over the treatments. The influence of T<sub>1</sub> (50 ppm GA<sub>3</sub>) was significantly superior to that of 100 ppm and 150 ppm GA<sub>3</sub> for the exhibition of dry weight when the average was made over genotypes. While considering the interaction between treatments and genotypes, a significantly maximum dry weight (0.120 g) was recorded for G<sub>2</sub> (PM-11-9), G<sub>6</sub> (IPM-512-1) and G<sub>4</sub> (Meha) followed by G<sub>7</sub> (TMB-37) after application of 50 ppm GA<sub>3</sub>, and lowest dry weight (0.040 g) was recorded for G<sub>8</sub> (SML-1822) when treated with 150 ppm of GA<sub>3</sub> and G<sub>3</sub> (IPM-2-3) when treated with 100 ppm of GA<sub>3</sub> preceded by G<sub>7</sub> (TMB-37) when treated with 150 ppm of GA<sub>3</sub> and G<sub>6</sub> (IPM-512-1) when treated with 100 ppm of GA<sub>3</sub>.

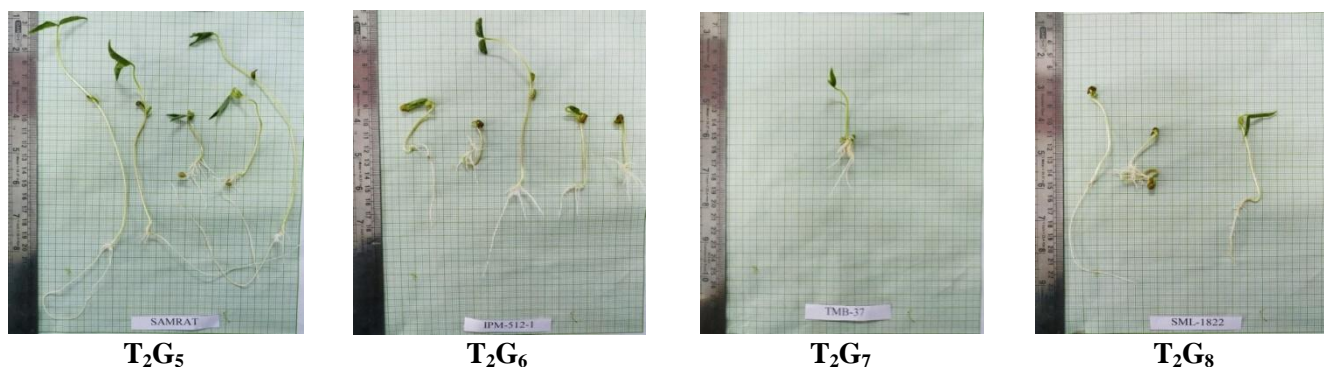
If ranking is made amongst the genotypes over treatments about its dry weight, it could be recorded as G<sub>2</sub>> G<sub>1</sub>> G<sub>7</sub>> G<sub>4</sub>> G<sub>6</sub>> G<sub>5</sub>> G<sub>3</sub>> G<sub>8</sub>.

**TABLE 4**  
**MEAN VALUE OF DRY WEIGHT OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF GA<sub>3</sub>**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	0.113	0.120	0.093	0.120	0.080	0.120	0.117	0.100	0.108
T <sub>2</sub>	0.110	0.093	0.040	0.087	0.080	0.063	0.113	0.067	0.082
T <sub>3</sub>	0.093	0.110	0.077	0.083	0.087	0.087	0.063	0.040	0.080
Mean G	0.106	0.108	0.070	0.097	0.082	0.090	0.098	0.069	
	T	G	TXG						
SEm(±)	0.002	0.003	0.005						
LSD	0.005	0.008	0.014						

T= GA<sub>3</sub>, T<sub>1</sub>= 50 ppm, T<sub>2</sub>= 100 ppm, T<sub>3</sub>= 150 ppm

G= Genotypes, G<sub>1</sub>= Pusa Vishal, G<sub>2</sub>= PM-11-9, G<sub>3</sub>= IPM-2-3, G<sub>4</sub>= Meha (IPM 99-125), G<sub>5</sub>= Samrat, G<sub>6</sub>= IPM-512-1, G<sub>7</sub>= TMB-37, G<sub>8</sub>= SML-1822.



**FIGURE 4: Images of germination and vigour test of green gram genotypes after priming with dose of 100 ppm GA<sub>3</sub> (T<sub>2</sub>).**

**3.5 Germination percentage of genotypes after priming with GA<sub>3</sub>**

When the average was made over the treatments, highest germination percentage (95.02 %) were noted for G<sub>5</sub> (Samrat) followed by G<sub>4</sub> (Meha), while lowest germination percentage (93.86 %) were recognized for G<sub>7</sub> (TMB-37) preceded by G<sub>8</sub> (SML-1822). The germination percentage of T<sub>1</sub> (50 ppm GA<sub>3</sub>) was significantly superior to that of 100 ppm and 150 ppm GA<sub>3</sub> when average was made over genotypes. In case of interaction between treatments and genotypes, maximum germination percentage (99.58 %) was recorded for G<sub>4</sub> (Meha) followed by G<sub>5</sub> (Samrat) after application of 50 ppm GA<sub>3</sub>, and lowest germination percentage (87.91 %) was recorded for G<sub>6</sub> (IPM-512-1) preceded by G<sub>7</sub> (TMB-37) when treated with 150 ppm of GA<sub>3</sub>.

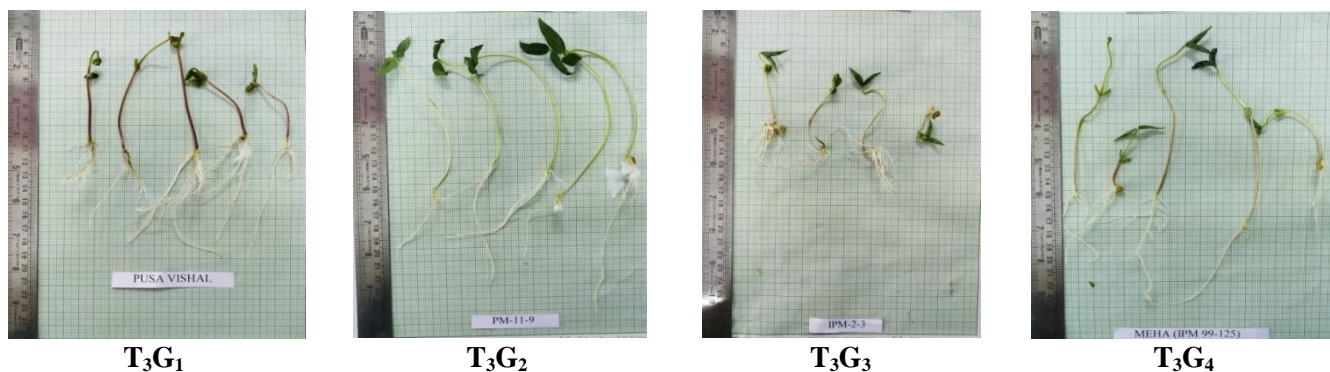
Ranking amongst the genotypes about its germination percentage over treatments is, G<sub>5</sub>> G<sub>4</sub>> G<sub>2</sub>> G<sub>1</sub>> G<sub>3</sub>> G<sub>6</sub>> G<sub>8</sub>> G<sub>7</sub>.

**TABLE 5**  
**MEAN VALUE OF GERMINATION PERCENTAGE OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF GA<sub>3</sub>**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	99.25 (85.045)	99.25 (85.045)	99 (84.257)	99.58 (86.399)	99.5 (86.002)	98.91 (84.130)	98.83 (83.825)	99 (84.356)	99.16 (84.882)
T <sub>2</sub>	94.66 (76.622)	94.5 (76.426)	94.91 (76.945)	95.41 (77.614)	95 (77.051)	95.66 (77.968)	94.58 (76.526)	94.83 (76.837)	94.94 (76.998)
T <sub>3</sub>	89.41 (70.988)	90.33 (71.859)	89.16 (70.758)	89.91 (71.459)	90.58 (72.103)	87.91 (69.632)	88.16 (69.856)	88.58 (70.225)	89.26 (70.860)
Mean G	94.44 (77.552)	94.69 (77.777)	94.36 (77.320)	94.97 (78.490)	95.02 (78.385)	94.16 (77.243)	93.86 (76.736)	94.13 (77.139)	
	T	G	TXG						
SEm(±)	0.161	0.262	0.454						
LSD	0.458	0.748	1.296						

T= GA<sub>3</sub>, T<sub>1</sub>= 50 ppm, T<sub>2</sub>= 100 ppm, T<sub>3</sub>= 150 ppm

G= Genotypes, G<sub>1</sub>= Pusa Vishal, G<sub>2</sub>= PM-11-9, G<sub>3</sub>= IPM-2-3, G<sub>4</sub>= Meha (IPM 99-125), G<sub>5</sub>= Samrat, G<sub>6</sub>= IPM-512-1, G<sub>7</sub>= TMB-37, G<sub>8</sub>= SML-1822.



**FIGURE 5: Images of germination and vigour test of green gram genotypes after priming with dose of 150 ppm GA<sub>3</sub> (T<sub>3</sub>).**

**3.6 Vigor Index of genotypes after priming with GA<sub>3</sub>**

Maximum vigor index (2,167.894) were observed for G<sub>5</sub> (Samrat) followed by G<sub>2</sub> (PM-11-9), while lowest vigor index (1,312.901) were recognized for G<sub>7</sub> (TMB-37) preceded by G<sub>6</sub> (IPM-512-1) when the average was made over the treatments. The average influence of T<sub>2</sub> i.e. 100 ppm and T<sub>3</sub> i.e. 150 ppm GA<sub>3</sub> was significantly inferior to that of T<sub>1</sub> (50 ppm GA<sub>3</sub>) for the exhibition of vigor index when the average was made over the genotypes. When the interaction between treatments and genotypes was considered, a significantly maximum vigor index (2,565.244) was recorded for G<sub>5</sub> (Samrat) followed by G<sub>2</sub> (PM-11-9) after application of 50 ppm GA<sub>3</sub>, while lowest vigor index (848.756) was recorded for G<sub>7</sub> (TMB-37) preceded by G<sub>3</sub> (IPM-2-3) when treated with 150 ppm of GA<sub>3</sub>.

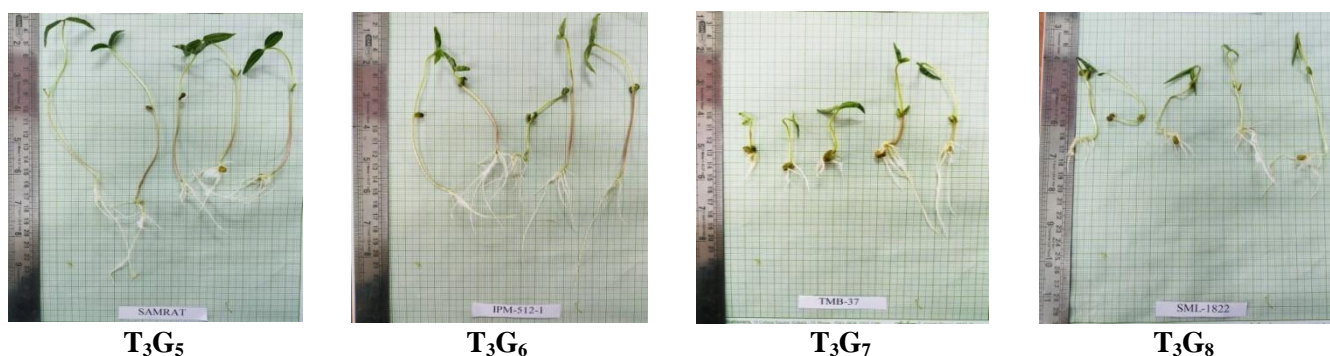
G<sub>5</sub>> G<sub>2</sub>> G<sub>1</sub>> G<sub>4</sub>> G<sub>3</sub>> G<sub>8</sub>> G<sub>6</sub>> G<sub>7</sub> is the ranking amongst the genotypes about its vigor index over treatments.

**TABLE 6  
MEAN VALUE OF VIGOR INDEX OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF GA<sub>3</sub>**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	2,049.508	2,426.335	2,122.565	1,818.915	2,565.244	1,648.607	1,684.125	1,828.197	2,017.937
T <sub>2</sub>	1,498.882	1,479.868	1,145.967	1,114.152	2,231.549	1,099.220	1,405.823	1,313.752	1,411.151
T <sub>3</sub>	1,397.586	1,698.267	929.724	1,480.634	1,706.888	1,393.473	848.756	1,016.055	1,308.923
Mean G	1,648.658	1,868.157	1,399.419	1,471.234	2,167.894	1,380.433	1,312.901	1,386.001	
	T	G	TXG						
SEm(±)	1.601	2.614	4.528						
LSD	4.566	7.456	12.914						

T = GA<sub>3</sub>, T<sub>1</sub> = 50 ppm, T<sub>2</sub> = 100 ppm, T<sub>3</sub> = 150 ppm

G = Genotypes, G<sub>1</sub> = Pusa Vishal, G<sub>2</sub> = PM-11-9, G<sub>3</sub> = IPM-2-3, G<sub>4</sub> = Meha (IPM 99-125), G<sub>5</sub> = Samrat, G<sub>6</sub> = IPM-512-1, G<sub>7</sub> = TMB-37, G<sub>8</sub> = SML-1822.



**FIGURE 6: Images of germination and vigour test of green gram genotypes after priming with dose of 150 ppm GA<sub>3</sub> (T<sub>3</sub>).**

### 3.7 Root length (cm) of genotypes after priming with Ag-Nanoparticle

Highest root lengths (8.691 cm) were observed for G<sub>7</sub> (TMB-37) followed by G<sub>5</sub> (Samrat), while shortest root lengths (5.222 cm) were recognized for G<sub>1</sub> (Pusa Vishal) preceded by G<sub>2</sub> (PM-11-9) when the average was made over the treatments. The influence of T<sub>1</sub> i.e. 10 ppm and T<sub>3</sub> i.e. 50 ppm Ag-Nanoparticle was significantly inferior to that of T<sub>2</sub> (20 ppm Ag-Nanoparticle) for the exhibition of root length when the average was made over the genotypes. While considering the interaction between treatments and genotypes, a significantly maximum root length (14.217 cm) was recorded for G<sub>3</sub> (IPM-2-3) followed by G<sub>4</sub> (Meha) after application of 20 ppm Ag-Nanoparticle, and shortest root length (3.017 cm) was recorded for G<sub>3</sub> (IPM-2-3) preceded by G<sub>4</sub> (Meha) when treated with 50 ppm of Ag-Nanoparticle.

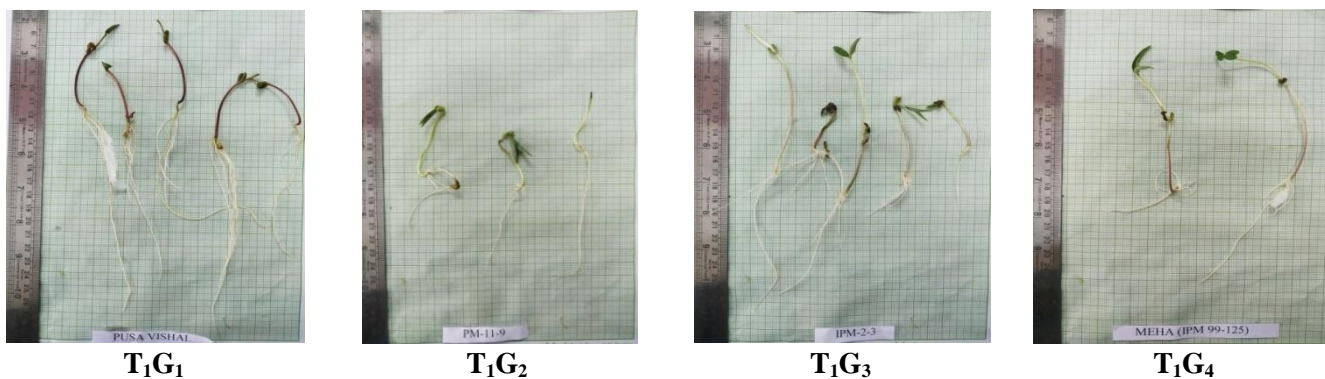
G<sub>7</sub>> G<sub>5</sub>> G<sub>4</sub>> G<sub>3</sub>> G<sub>8</sub>> G<sub>6</sub>> G<sub>2</sub>> G<sub>1</sub> is the ranking amongst the genotypes about its root length over treatments.

**TABLE 7**  
**MEAN VALUE OF ROOT LENGTH OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF Ag-NANOPARTICLE**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	5.623	6.823	6.830	10.013	7.820	8.423	9.827	9.223	8.073
T <sub>2</sub>	6.223	11.027	14.217	11.420	11.030	9.423	10.820	9.820	10.498
T <sub>3</sub>	3.820	3.640	3.017	3.223	6.030	3.823	5.427	3.320	4.038
Mean G	5.222	7.163	8.021	8.219	8.293	7.223	8.691	7.454	
	T	G	TXG						
SEm(±)	0.005	0.008	0.014						
LSD	0.014	0.022	0.039						

T = Ag-Nanoparticle, T<sub>1</sub> = 10 ppm, T<sub>2</sub> = 20 ppm, T<sub>3</sub> = 50 ppm

G = Genotypes, G<sub>1</sub> = Pusa Vishal, G<sub>2</sub> = PM-11-9, G<sub>3</sub> = IPM-2-3, G<sub>4</sub> = Meha (IPM 99-125), G<sub>5</sub> = Samrat, G<sub>6</sub> = IPM-512-1, G<sub>7</sub> = TMB-37, G<sub>8</sub> = SML-1822.



**FIGURE 7: Images of germination and vigour test of green gram genotypes after priming with dose of 10 ppm Ag-nanoparticle (T<sub>1</sub>).**

### 3.8 Shoot Length (cm) of genotypes after priming with Ag-Nanoparticle

Shortest shoot lengths (6.617 cm) were recognized for G<sub>4</sub> (Meha) preceded by G<sub>6</sub> (IPM-512-1) whereas highest shoot lengths (9.554 cm) were observed for G<sub>1</sub> (Pusa Vishal) followed by G<sub>7</sub> (TMB-37) when the average was made over the treatments. When the average was made over the genotypes, the influence of T<sub>2</sub> (20 ppm Ag-Nanoparticle) was significantly superior to that of 10 ppm and 50 ppm Ag-Nanoparticle for the exhibition of shoot length. When the interaction between treatments and genotypes was considered, a significantly maximum shoot length (13.817 cm) was recorded for G<sub>1</sub> (Pusa Vishal) followed by G<sub>3</sub> (IPM-2-3) after application of 20 ppm Ag-Nanoparticle, and shortest shoot length (2.210 cm) was recorded for G<sub>4</sub> (Meha) preceded by G<sub>2</sub> (PM-11-9) when treated with 50 ppm of Ag-Nanoparticle.

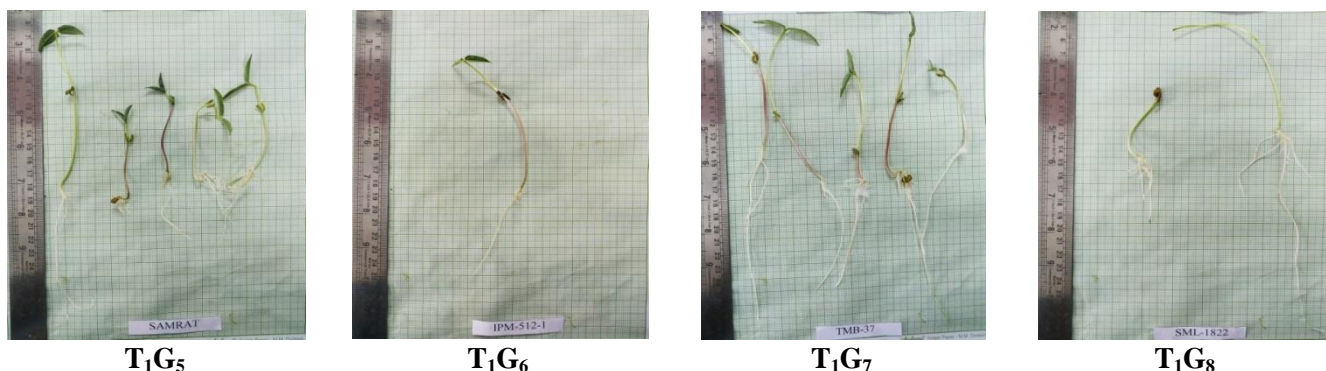
If ranking is made amongst the genotypes about its shoot length over treatments, it could be noted as G<sub>1</sub>> G<sub>7</sub>> G<sub>5</sub>> G<sub>2</sub>> G<sub>3</sub>> G<sub>8</sub>> G<sub>6</sub>> G<sub>4</sub>.

**TABLE 8**  
**MEAN VALUE OF SHOOT LENGTH OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF Ag-NANOPARTICLE**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	10.620	8.010	6.423	7.627	6.617	7.650	10.250	7.013	8.026
T <sub>2</sub>	13.817	11.037	11.623	10.013	10.423	8.223	10.827	9.420	10.673
T <sub>3</sub>	4.227	2.830	3.423	2.210	5.620	4.033	4.430	4.630	3.925
Mean G	9.554	7.292	7.157	6.617	7.553	6.636	8.502	7.021	
	T	G	TXG						
SEm(±)	0.005	0.008	0.014						
LSD	0.014	0.024	0.041						

T = Ag-Nanoparticle, T<sub>1</sub> = 10 ppm, T<sub>2</sub> = 20 ppm, T<sub>3</sub> = 50 ppm

G = Genotypes, G<sub>1</sub> = Pusa Vishal, G<sub>2</sub> = PM-11-9, G<sub>3</sub> = IPM-2-3, G<sub>4</sub> = Meha (IPM 99-125), G<sub>5</sub> = Samrat, G<sub>6</sub> = IPM-512-1, G<sub>7</sub> = TMB-37, G<sub>8</sub> = SML-1822.



**FIGURE 8: Images of germination and vigour test of green gram genotypes after priming with dose of 10 ppm Ag-nanoparticle (T<sub>1</sub>).**

**3.9 Fresh weight (g) of genotypes after priming with Ag-Nanoparticle**

Significantly highest fresh weight (0.921 g) were observed for G<sub>1</sub> (Pusa Vishal) followed by G<sub>7</sub> (TMB-37), while lowest fresh weight (0.214 g) were recognized for G<sub>6</sub> (IPM-512-1) preceded by G<sub>4</sub> (Meha) when the average was made over the treatments. The average influence of T<sub>2</sub> (20 ppm Ag-Nanoparticle) was significantly superior to that of 10 ppm and 50 ppm Ag-Nanoparticle for the exhibition of fresh weight when the average was made over the genotypes. While considering the interaction between treatments and genotypes, a significantly maximum fresh weight (1.170 g) was recorded for G<sub>1</sub> (Pusa Vishal) followed by G<sub>3</sub> (IPM-2-3) after application of 20 ppm Ag-Nanoparticle, and lowest fresh weight (0.110 g) was recorded for G<sub>6</sub> (IPM-512-1) treated with 50 ppm of Ag-Nanoparticle preceded by the same genotype when treated with 10 ppm of Ag-Nanoparticle.

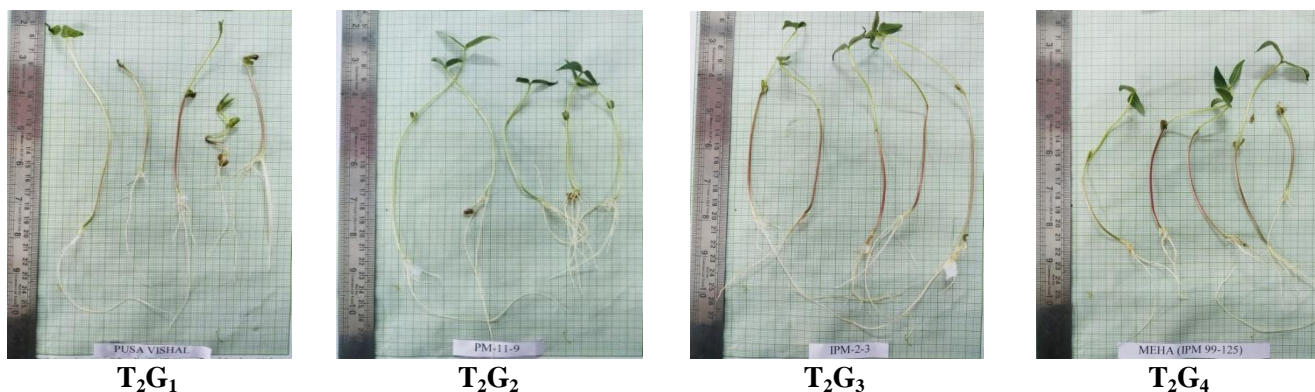
G<sub>1</sub> > G<sub>7</sub> > G<sub>3</sub> > G<sub>5</sub> > G<sub>2</sub> > G<sub>8</sub> > G<sub>4</sub> > G<sub>6</sub> is the ranking about its fresh weight over treatments amongst the genotypes.

**TABLE 9**  
**MEAN VALUE OF FRESH WEIGHT OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF AG-NANOPARTICLE**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	0.990	0.760	0.860	0.340	0.700	0.217	0.910	0.403	0.648
T <sub>2</sub>	1.170	0.880	1.040	1.030	1.013	0.317	0.980	0.880	0.914
T <sub>3</sub>	0.603	0.270	0.527	0.330	0.507	0.110	0.663	0.577	0.448
Mean G	0.921	0.637	0.809	0.567	0.740	0.214	0.851	0.620	
	T	G	TXG						
SEm(±)	0.002	0.003	0.005						
LSD	0.005	0.008	0.014						

T = Ag-Nanoparticle, T<sub>1</sub> = 10 ppm, T<sub>2</sub> = 20 ppm, T<sub>3</sub> = 50 ppm

G = Genotypes, G<sub>1</sub> = Pusa Vishal, G<sub>2</sub> = PM-11-9, G<sub>3</sub> = IPM-2-3, G<sub>4</sub> = Meha (IPM 99-125), G<sub>5</sub> = Samrat, G<sub>6</sub> = IPM-512-1, G<sub>7</sub> = TMB-37, G<sub>8</sub> = SML-1822.



**FIGURE 9: Images of germination and vigour test of green gram genotypes after priming with dose of 20 ppm Ag-nanoparticle (T<sub>2</sub>).**

**3.10 Dry weight (g) of genotypes after priming with Ag-Nanoparticle**

Highest dry weight (0.081 g) were observed for G<sub>3</sub> (IPM-2-3) followed by G<sub>7</sub> (TMB-37) when the average was made over the treatments, while lowest dry weight (0.043 g) were recognized for G<sub>6</sub> (IPM-512-1) preceded by G<sub>4</sub> (Meha). While considering the interaction between treatments and genotypes, lowest dry weight (0.027 g) was recorded for G<sub>4</sub> (Meha) preceded by G<sub>6</sub> (IPM-512-1) when treated with 50 ppm of Ag-Nanoparticle and a significantly maximum dry weight (0.117 g) was recorded for G<sub>2</sub> (PM-11-9) followed by G<sub>3</sub> (IPM-2-3) after application of 20 ppm Ag-Nanoparticle. When the average was made over the genotypes, the influence of T<sub>2</sub> (20 ppm Ag-Nanoparticle) was significantly superior to that of 10 ppm and 50 ppm Ag-Nanoparticle for the exhibition of dry weight.

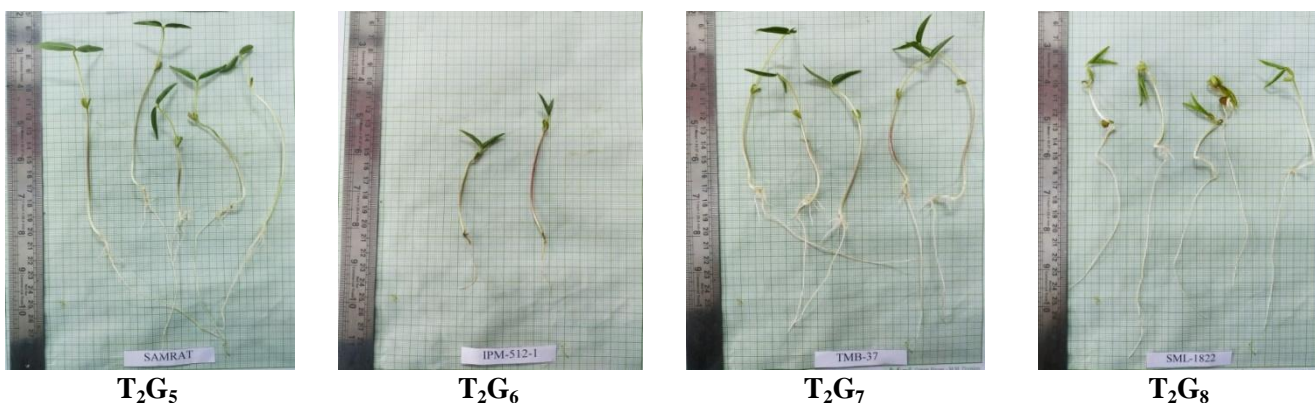
When the ranking is made amongst the genotypes about its dry weight over treatments, it could be observed as G<sub>3</sub>> G<sub>7</sub>> G<sub>1</sub>= G<sub>2</sub>> G<sub>8</sub>> G<sub>5</sub>> G<sub>4</sub>> G<sub>6</sub>.

**TABLE 10  
MEAN VALUE OF DRY WEIGHT OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF AG-NANOPARTICLE**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
<b>T<sub>1</sub></b>	0.080	0.053	0.083	0.040	0.043	0.040	0.087	0.040	0.058
<b>T<sub>2</sub></b>	0.040	0.117	0.093	0.077	0.087	0.060	0.073	0.090	0.080
<b>T<sub>3</sub></b>	0.083	0.033	0.067	0.027	0.037	0.030	0.080	0.060	0.052
<b>Mean G</b>	0.068	0.068	0.081	0.048	0.056	0.043	0.080	0.063	
	<b>T</b>	<b>G</b>	<b>TXG</b>						
<b>SEm(±)</b>	<b>0.002</b>	<b>0.003</b>	<b>0.005</b>						
<b>LSD</b>	<b>0.005</b>	<b>0.007</b>	<b>0.013</b>						

T = Ag-Nanoparticle, T<sub>1</sub> = 10 ppm, T<sub>2</sub> = 20 ppm, T<sub>3</sub> = 50 ppm

G = Genotypes, G<sub>1</sub> = Pusa Vishal, G<sub>2</sub> = PM-11-9, G<sub>3</sub> = IPM-2-3, G<sub>4</sub> = Meha (IPM 99-125), G<sub>5</sub> = Samrat, G<sub>6</sub> = IPM-512-1, G<sub>7</sub> = TMB-37, G<sub>8</sub> = SML-1822.



**FIGURE 10: Images of germination and vigour test of green gram genotypes after priming with dose of 20 ppm Ag-nanoparticle (T<sub>2</sub>).**

### 3.11 Germination percentage of genotypes after priming with Ag-Nanoparticle

The influence of T<sub>2</sub> (20 ppm Ag-Nanoparticle) was significantly superior to that of 10 ppm and 50 ppm Ag-Nanoparticle for the exhibition of germination percentage when the average was made over the genotypes. Highest germination percentage (90.55 %) were observed for G<sub>2</sub> (PM-11-9) followed by G<sub>5</sub> (Samrat), while lowest germination percentage (89.19 %) were recognized for G<sub>3</sub> (IPM-2-3) preceded by G<sub>7</sub> (TMB-37) when the average was made over the treatments. When the interaction between treatments and genotypes was considered, highest germination percentage (99.5 %) was recorded for G<sub>1</sub> (Pusa Vishal) and G<sub>2</sub> (PM-11-9) followed by G<sub>6</sub> (IPM-512-1) after application of 20 ppm Ag-Nanoparticle, and lowest germination percentage (78.91 %) was recorded for G<sub>7</sub> (TMB-37) and G<sub>3</sub> (IPM-2-3) preceded by G<sub>4</sub> (Meha) when treated with 50 ppm of Ag-Nanoparticle.

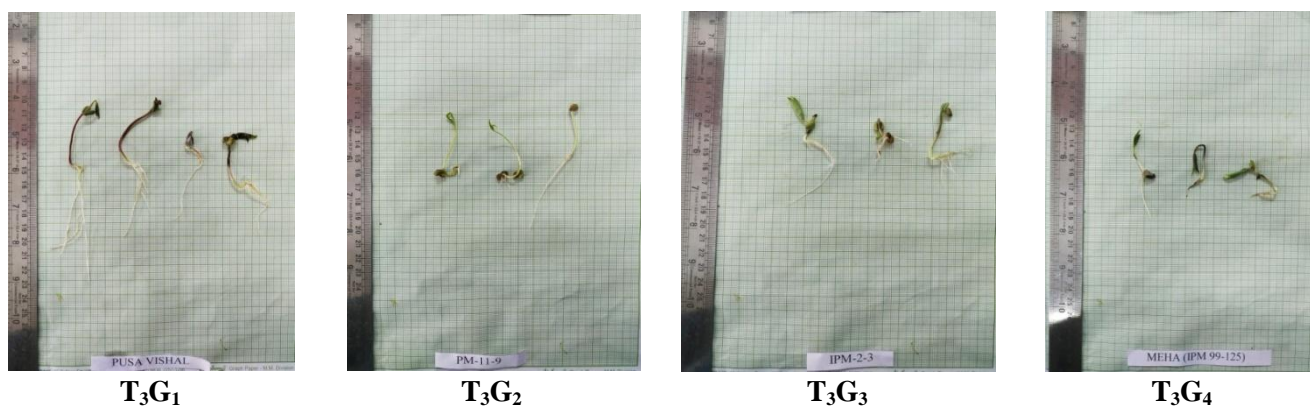
G<sub>2</sub>> G<sub>5</sub>> G<sub>8</sub>> G<sub>6</sub>> G<sub>1</sub>> G<sub>4</sub>> G<sub>7</sub>> G<sub>3</sub> is the ranking about its germination percentage over treatments amongst the genotypes.

**TABLE 11**  
**MEAN VALUE OF GERMINATION PERCENTAGE OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF AG-NANOPARTICLE**

<b>T<sub>1</sub></b>	90.33 (71.859)	91 (72.517)	89.41 (70.988)	90.33 (71.859)	90.83 (72.350)	88.91 (70.529)	89.83 (71.381)	91.25 (72.772)	90.23 (71.782)
<b>T<sub>2</sub></b>	99.5 (86.002)	99.5 (86.002)	99.25 (85.045)	99.25 (85.215)	99.08 (84.613)	99.41 (85.746)	99.25 (85.045)	99.25 (85.045)	99.31 (85.339)
<b>T<sub>3</sub></b>	80.08 (63.470)	81.16 (64.255)	78.91 (62.643)	79.66 (63.173)	81.58 (64.563)	81.83 (64.747)	78.91 (62.643)	80.08 (63.470)	80.28 (63.620)
<b>Mean G</b>	89.97 (73.777)	90.55 (74.258)	89.19 (72.892)	89.75 (73.416)	90.5 (73.842)	90.05 (73.674)	89.33 (73.023)	90.19 (73.763)	
	<b>T</b>	<b>G</b>	<b>TXG</b>						
<b>SEm(±)</b>	<b>0.160</b>	<b>0.262</b>	<b>0.453</b>						
<b>LSD</b>	<b>0.457</b>	<b>0.746</b>	<b>1.292</b>						

T = Ag-Nanoparticle, T<sub>1</sub> = 10 ppm, T<sub>2</sub> = 20 ppm, T<sub>3</sub> = 50 ppm

G = Genotypes, G<sub>1</sub> = Pusa Vishal, G<sub>2</sub> = PM-11-9, G<sub>3</sub> = IPM-2-3, G<sub>4</sub> = Meha (IPM 99-125), G<sub>5</sub> = Samrat, G<sub>6</sub> = IPM-512-1, G<sub>7</sub> = TMB-37, G<sub>8</sub> = SML-1822.



**FIGURE 11: Images of germination and vigour test of green gram genotypes after priming with dose of 50 ppm Ag-nanoparticle (T<sub>3</sub>).**

### 3.12 Vigor Index of genotypes after priming with Ag-Nanoparticle

In case of considering the interaction between treatments and genotypes, a significantly maximum vigor index (2,564.625) was recorded for G<sub>3</sub> (IPM-2-3) followed by G<sub>2</sub> (PM-11-9) after application of 20 ppm Ag-Nanoparticle, and minimum vigor index (432.854) was recorded for G<sub>4</sub> (Meha) preceded by G<sub>3</sub> (IPM-2-3) when treated with 50 ppm of Ag-Nanoparticle. Significantly maximum vigor index (1,576.616) were observed for G<sub>7</sub> (TMB-37) followed by G<sub>5</sub> (Samrat), while lowest vigor index (1,275.502) were recognized for G<sub>6</sub> (IPM-512-1) preceded by G<sub>8</sub> (SML-1822) when the average was made over the treatments. The influence of T<sub>2</sub> (20 ppm Ag-Nanoparticle) was significantly superior to that of T<sub>1</sub> i.e. 10 ppm and T<sub>3</sub> i.e. 50 ppm Ag-Nanoparticle for the exhibition of vigor index when the average was made over the genotypes.

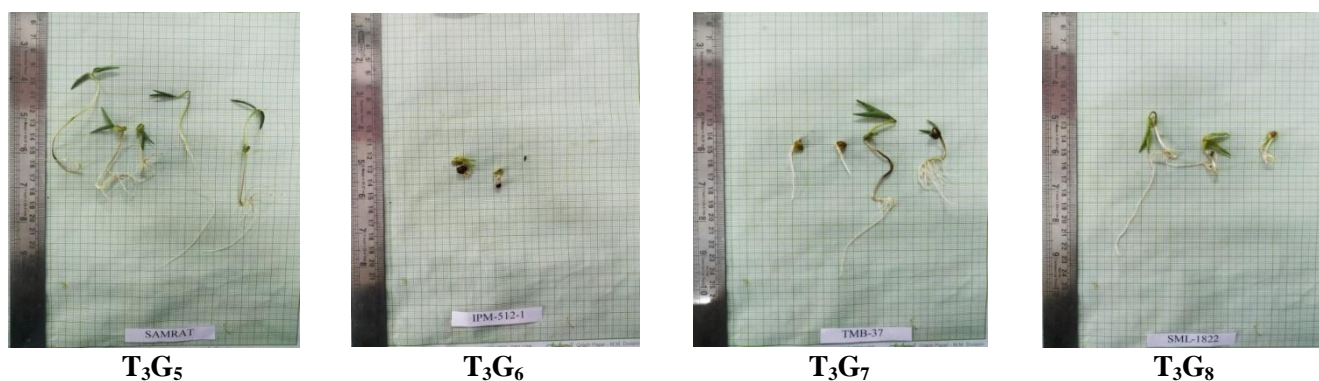
Ranking amongst the genotypes about its vigor index over treatments is G<sub>7</sub>> G<sub>5</sub>> G<sub>1</sub>> G<sub>3</sub>> G<sub>4</sub>> G<sub>2</sub>> G<sub>8</sub>> G<sub>6</sub>.

**TABLE 12**  
**MEAN VALUE OF VIGOR INDEX OF DIFFERENT GREEN GRAM GENOTYPES AFTER TREATED WITH DIFFERENT DOSES OF AG-NANOPARTICLE**

	G <sub>1</sub>	G <sub>2</sub>	G <sub>3</sub>	G <sub>4</sub>	G <sub>5</sub>	G <sub>6</sub>	G <sub>7</sub>	G <sub>8</sub>	Mean T
T <sub>1</sub>	1,647.989	1,349.837	1,185.080	1,593.469	1,311.331	1,429.190	1,803.558	1,481.616	1,475.259
T <sub>2</sub>	1,993.978	2,197.150	2,564.625	2,127.255	2,125.683	1,754.363	2,148.427	1,909.576	2,102.632
T <sub>3</sub>	644.396	525.144	508.209	432.854	950.459	642.954	777.862	636.658	639.817
Mean G	1,428.788	1,357.377	1,419.305	1,384.526	1,462.491	1,275.502	1,576.616	1,342.617	
	T	G	TXG						
SEm(±)	1.769	2.889	5.004						
LSD	5.046	8.240	14.273						

T= Ag-Nanoparticle, T<sub>1</sub>= 10 ppm, T<sub>2</sub>= 20 ppm, T<sub>3</sub>= 50 ppm

G= Genotypes, G<sub>1</sub>= Pusa Vishal, G<sub>2</sub>= PM-11-9, G<sub>3</sub>= IPM-2-3, G<sub>4</sub>= Meha (IPM 99-125), G<sub>5</sub>= Samrat, G<sub>6</sub>= IPM-512-1, G<sub>7</sub>= TMB-37, G<sub>8</sub>= SML-1822.



**FIGURE 12: Images of germination and vigour test of green gram genotypes after priming with dose of 50 ppm Ag-nanoparticle (T<sub>3</sub>).**

#### IV. CONCLUSION

The various seed quality parameters such as root length, shoot length, seedling dry weight, fresh weight, germination percentage and vigor index were highest when priming with 50 ppm of GA<sub>3</sub> and 20 ppm of Ag-nanoparticle was done. So, it can be concluded that 50 ppm of GA<sub>3</sub> and 20 ppm of Ag-nanoparticle doses are appropriate for quality seed production.

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