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Effect of Seed Priming Using GA_3, KNO_3, $ZnSO_4$ on Germination Parameters of *Vigna unguiculata*

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ABSTRACT

Cowpeas (*Vigna unguiculata)*, an important legume is a versatile crop, also commonly known as southern pea, black eye pea, crowder pea, lubia, niebe, coupea or Frijole. The establishment of this crop is poor due to poor germination. Seed priming technique helps to overcome this difficulty. There is only less research have been carried out to enhance seed germination in cowpea by seed priming technique. This research paper focuses to study on the effects of different priming agents like GA_3 at 20 ppm, 40 ppm and 60 ppm, KNO_3 at 1 %, 2%, 3%, $ZnSO_4$ at 1 %, 2%, 3% and hydro priming all in 3 hrs and 6 hrs soaking conditions. The untreated seeds serve as control. The result from the present study revealed that the germination parameters viz., germination value, germination index, imbibition, co-efficient of variation of germination, seed length, root length, seedling length, vigor index were at its maximum for the seeds primed with GA_3 at 60 ppm, KNO_3 at 2% and $ZnSO_4$ at 2%. Priming of seeds at lower concentration improves the seed germination parameters which in turn increases the yield.

Keywords Seed priming, Hydro priming, Osmo priming, Hormonal priming, Nutri priming, Nano priming.

INTRODUCTION

Cowpea also known as *Vigna unguiculata* belong to the family of Fabaceae. It was originated in Africa. It is known by the local names as Lobia in India, Caupi in Brazil, long bean in China. Humans use cowpea as food, fodder for cattles and as manure for agricultural purposes. Cowpea can be grown for its grain, pod as vegetable, leaves as fodder, hay, silage, mulching material, intercrop with many cereal crops, fixes atmospheric nitrogen and many more. The protein content is around 22.4%, carbohydrate 55–66%, iron levels varied from 2.0 to 2.4 mg/1 kg seeds, whereas calcium levels ranged from 9 to 36 mg/100 g (Gondwe *et al.* 2019). It also contains vitamins such as thiamine, riboflavin and niacin, aminocaids like lysine, leucine and phenylalanine. As the crop has many uses the production of crop is very low in developing countries due to the usage of seeds which are not stored in a proper way. The lack of knowledge about handling of seeds after harvesting, nutritional qualities of the seeds and the production practices are some of the reasons for low production. The seeds stored by the farmers does not achieve recommended seed standards to uses as a seed. Many researchers have

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confirmed this (Eskandari and Kazemi 2011, Kamara *et al.* 2019, Njonjo *et al.* 2019). Seed priming may improve germination parameters like germination index, seed vigour, reduce emergence time, imbibition, speed of germination. Seed priming is a process by which seeds are induced into a state of pre-germinative metabolism by controlled rehydration to increase germination rates and germination vigor (Paparella *et al.* 2015). In this method seeds are hydrated up to a point where pre germinative metabolic activities may continue but radicle emergence is prevented. Seed priming with different priming methods like hydropriming, osmo priming, hormonal priming, nutri priming, nano priming can be done to improve the germination, uniform seedling establishment as these are essential stage of a plant life. In the present study seed priming was done using three agents viz., GA_3, KNO_3 and $ZnSO_4$. GA_3 helps to overcome seed dormancy arising due to weak endosperm. Priming of sunflower seeds (Ulfat *et al.* 2017) and wheat seeds (Jafri *et al.* 2015) with GA_3 increased seed yield. Seed priming with KNO_3 incerases seed germination and seed priming with $ZnSO_4$ doubled the yield in maize. These three agents are easily available to farmers. Hydropriming has many advantages which has been shown in many crops viz., wheat (Harris *et al.* 2001), chickpea (Musa *et al.* 2001), maize (Ashraf and Rauf 2001), sunflower (Kaya *et al.* 2006) and barley (Abdulrahmani *et al.* 2007). But not many authors investigated the effects of seed priming in cowpea. Hence, this research was aimed to investigate the effects of priming using GA_3, KNO_3 and $ZnSO_4$ and hydropriming for 3 hrs and 6 hrs soaking time at three concentrations on germination parameters of this crop.

MATERIALS AND METHODS

The study was conducted using genetically pure seeds of cowpea cv VBN 3 obtained from Krishi Vigyan Kendra, Sandhiyur, Tamil Nadu. The experiment was conducted at the Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar (11°24 N latitude and 79°44 'E longitude with an altitude of +5.79 m above mean sea level) with four replications in a Factorial Completely Randomized Block Design (FCRD) in three sets. The bulk seeds were first dried to below 9% moisture content, cleaned, and then graded with suitable sieves. The concentrations of the priming agents as factor 1 and factor 2 being the duration of soaking hours. Their treatment details are given in Table 1.

Table 1. Priming agents, their concentrations, and duration of priming in cowpea cv VBN 3.

Priming agent		Concentration (Factor 1)	Duration of soaking (h) (Factor 2)
	Hydropriming		
Set 1	GA_3	20 ppm	3 and 6
		40 ppm	
		60 ppm	
	Control	–	–
	Hydropriming	–	
Set 2	KNO_3	1%	3 and 6
		2%	
		3%	
	Control	–	–
Set 3	Hydropriming	–	
	$ZnSO_4$	1%	
		2%	3 and 6
		3%	
	Control	–	–

Seeds were treated with their respective solutions for a specified duration. Following treatment, the seeds were extracted from the solutions, rinsed with water two to three times, air-dried in shade until they regained their original moisture content, and evaluated for various seed quality parameters, such as germination index, root length, shoot length, dry weight, seedling length (cm), mean germination rate and time (Ranal *et al.* 2009), imbibition rate (Tian *et al.* 2014), water content, speed of germination, germination percentage, peak value germination value, (Czabator 1962) days to 50% germination, germination percentage and vigour index were recorded with hydroprimed seeds and control in each set. Germination test was performed using glassplate and petri-plate method and Germination (%) = No. of normal seedlings germinated × 100/ Total no. of seeds placed for germination. Speed of germination was calculated according to the equation of Ellis and Roberts (1981): $MGT = \sum(n \times d) / N$, where N = Number of seeds germinated on each day, D = Number of days from the beginning of the test, and N

Table 2. Effect of seed priming using GA_3 on water content imbibition rate, germination (%) and mean germination time and mean germination rate of *Vigna unguiculata.*

Priming agen	Water content Soaking duration in h (d)			Imbition rate Soaking duration in h (d)			Germination % Soaking hrs			Mean germination time Soaking hrs			Mean germination rate Soaking hrs		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	13.74	13.96	13.85	1.164	1.258	1.211	84	80	82	4.593	4.338	4.045	0.218	0.21	0.214
GA_3 20 ppm	14.34	15.05	14.7	1.163	1.344	1.253	85	82	84	4.322	4.343	4.332	0.233	0.23	0.232
GA_3 40 ppm	13.88	15.35	14.62	1.159	1.383	1.271	89	86	88	4.112	4.444	4.278	0.246	0.226	0.236
GA_3 60 ppm	**16.04**	**14.2**	**15.12**	**1.243**	**1.156**	**1.2**	**92**	**87**	**90**	**3.91**	**4.181**	**4.466**	**0.258**	**0.233**	**0.245**
Mean	12.08	11.23	11.65	0.946	1.028	0.987	75	75	75	3.2	3.2	3.2	0.19	0.19	0.19
C							84	83	83	4.027	4.101	4.264	0.229	0.218	0.223
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.096	0.152	0.215	0.008	0.012	0.018	0.501	0.792	1.121	0.023	0.037	0.052	0.001	0	0.003
SEd	0.133	0.21	0.298	0.011	0.017	0.025	0.708	1.121	1.585	0.033	0.052	0.074	0.001	0.003	0.004
Cd (p = 0.05)	0.286	0.452	0.639	0.024	0.037	0.053	1.489	2.355	3.33	0.07	0.111	0.157	0.004	0.006	0.009

= Total number of seeds germinated at the termination of the experiment . Root length and shoot length test was carried out by glassplate method. Vigor Index was also calculated by Abdul-Baki and Anderson (1973) as Vigor index-I = Germination (%) × Seedling length (cm). Vigor index -II= Germination (%) × Seedling dry weight (g). Data from the experiment underwent analysis using the 'F' test for significance, as outlined by Panse and Sukhatme (1985). In cases where necessary, percentage values were converted to angular (arc-sine) values before analysis. Critical differences (CD) were determined at a 5% probability level. Non-significant results from the 'F' test were denoted by the abbreviation NS.

RESULTS AND DISCUSSION

Significant differences were observed in all the seed and seedling quality parameters in Cowpea VBN 3 due to the priming agents and priming duration. The interaction effect between priming treatments and durations was also significant for germination characters, seedling length, dry matter production and vigor index. Between the soaking durations of 3 and 6 hrs, three hours of soaking recorded the maximum physiological and morphological parameters of seed

Table 3. Effect of seed priming using GA_3 on mean daily germination, peak value, CV, CVG and germination index of *Vigna unguiculata*.

Priming agent	Mean Daily Germination % Soaking hrs			Peak Value Soaking hrs			(CV_t) Soaking hrs			(CVG) Soaking hrs			Germination Index Soaking hrs		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	10.5	10.167	10.333	12.85	12.45	12.65	29.403	30.261	29.832	21.95	21.5	21.73	5.61	5.32	5.47
GA_3 20 ppm	10.667	10.833	10.75	13.87	13.56	13.71	31.318	32.49	31.904	23.3	23.03	23.17	5.48	5.71	5.6
GA_3 40 ppm	11	9.345	10.173	14.82	13.75	14.29	32.78	30.883	31.831	24.58	22.56	23.57	5.97	5.71	5.84
GA_3 60 ppm	**11.5**	**10.167**	**10.834**	**15.07**	**14.1**	**14.59**	**38.359**	**33.756**	**36.058**	**25.85**	**23.25**	**24.55**	**6.22**	**5.67**	**5.94**
Mean	9.33	9.33	9.33	11.5	11.5	11.5	30.043	30.043	30.043	20.12	20.12	20.12	5.13	5.13	5.13
C	10.599	9.968	10.284	13.62	13.07	13.35	32.381	31.487	31.934	23.16	22.09	22.63	5.68	5.51	5.6
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.062	0.098	0.139	0.078	0.124	0.175	0.182	0.288	0.407	0.138	0.218	0.309	0.034	0.053	0.076
SEd	0.088	0.139	0.197	0.111	0.175	0.248	0.257	0.407	0.576	0.195	0.309	0.437	0.048	0.076	0.107
Cd (p = 0.05)	0.185	0.292	0.414	0.233	0.369	0.522	0.542	0.856	1.211	0.411	0.65	0.92	0.101	0.16	0.226

Table 4. Effect of seed priming using GA_3 on, shoot length, root length, seedling length, vigor index I and vigor index II of *Vigna unguiculata*.

Priming agent	Shoot length (cm) Soaking hrs			Root length (cm) Soaking hrs			Seedling length (cm) Soaking hrs			Vigor index I Soaking duration in h (d)			Vigor index II Soaking duration in h (d)		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	14.9	14	14.45	10.3	9.8	10.05	26.9	23.8	25.35	2260	1936	2098	73	44	58
GA_3 20 ppm	17.1	16.6	16.85	12	10.3	11.15	29.1	26.9	28	2483	2331	2407	65	36	50
GA_3 40 ppm	16.6	15.2	15.9	11.4	9.8	10.6	26.3	25	25.65	2314	2267	2291	48	59	53
GA_3 60 ppm	**18.2**	**16.6**	**17.4**	**13**	**9.5**	**11.25**	**31.2**	**26.1**	**28.65**	**2870**	**2332**	**2601**	**109**	**80**	**95**
Mean	10.1	10.1	10.1	6.7	6.7	6.7	16.8	16.8	16.8	1254	1254	1254	25	25	25
C	15.38	14.5	14.94	10.68	9.22	9.95	26.06	23.72	24.89	2236	2024	2130	64	49	56
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.086	0.137	0.194	0.061	0.096	0.136	0.147	0.233	0.329	13.573	21.461	30.351	0.433	0.685	0.968
SEd	0.12	0.194	0.274	0.086	0.136	0.192	0.208	0.329	0.465	19.195	30.35	42.921	0.612	0.968	1.37
Cd (p = 0.05)	0.258	0.408	0.577	0.181	0.286	0.405	0.437	0.692	0.979	40.328	63.765	90.178	1.287	2.035	2.878

and seedling quality parameters compared to control.

In the current research the seeds of VBN_3 were primed using GA_3 at 20, 40 and 60 ppm, KNO_3 and $ZnSO_4$ at three different concentrations viz., 1%, 2% and 3% along with hydropriming. Among all the treatments values for all the germination parameters were higher in the seeds soaked for three hours than for six hours.

Effect of GA_3

In the current research cowpea seeds were primed using 3 concentrations viz., 20, 40 and 60 ppm. The uptake of water by seeds is the first phase in seed germination which is called as imbibition. The principle of seed priming is based on seed imbibition (Ruttanaruangboworn *et al.* 2017). Water content and seed imbibition rate was higher in the seeds primed with GA_3 at 60 ppm concentration for 3 hrs (Table 2). Germination percentage was the highest in GA_3 60 ppm concentration soaked for 3 hrs. The important impact of GA_3 is the enhancement of seed germination, which has been demonstrated in ornamental plants (Joshi *et al.* 2022). During germination, GA_3 is

Table 5. Effect of seed priming using KNO_3 on water content imbibition rate, germination (%) and mean germination time and mean germination rate of *Vigna unguiculata*.

Priming agent	Water content Soaking duration in h (d)			Imbition rate Soaking duration in h (d)			Germination % Soaking hrs			Mean germination time Soaking hrs			Mean germination rate Soaking hrs		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	13.89	13.44	13.67	1.01	1.1	1.05	83	81	82	4.2	4.1	4.15	0.21	0.215	0.213
KNO_3 1%	14.95	12.92	13.94	1.32	1.13	1.22	88	83	86	4.16	4.14	4.15	0.242	0.244	0.243
KNO_3 2%	**15.44**	**13.81**	**14.63**	**1.54**	**1.07**	**1.3**	**89**	**87**	**88**	**4.83**	**4.32**	**4.58**	**0.287**	**0.241**	**0.264**
KNO_3 3%	12.01	14.09	13.05	0.96	1.18	1.07	87	80	84	4.25	4.44	4.35	0.221	0.222	0.221
Mean	11.26	10.85	11.06	0.97	0.89	0.93	79	79	79	3.6	3.6	3.6	0.19	0.19	0.19
C							85	82	84	4.21	4.12	4.16	0.23	0.222	0.226
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.094	0.148	0.21	0.008	0.013	0.019	0.465	0.735	1.04	0.026	0.041	0.058	0.001	0.002	0.003
SEd	0.13	0.206	0.291	0.011	0.018	0.026	0.657	1.04	1.471	0.036	0.058	0.082	0.002	0.003	0.004
Cd (p = 0.05)	0.279	0.442	0.625	0.025	0.039	0.056	1.382	2.185	3.09	0.077	0.122	0.173	0.004	0.007	0.009

Table 6. Effect of seed priming using KNO_3 on mean daily germination, peak value, CV, CVG and germination index of *Vigna unguiculata*.

Priming agent	Mean daily germination % Soaking hrs			Peak value Soaking hrs			(CV_t) Soaking hrs			(CVG) Soaking hrs			Germination index Soaking hrs		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	10.2	10.17	10.18	13.93	12.93	13.43	30.45	30.72	30.59	22.11	22.17	22.14	5.3	5.4	5.35
KNO_3 1%	10.5	10.32	10.41	14.04	14.48	14.26	34.5	33.64	34.07	24.18	24.36	24.27	5.7	5.8	5.75
KNO_3 2%	**11.48**	**10.53**	**11.01**	**14.8**	**14.27**	**14.53**	**39.16**	**35.05**	**37.11**	**26.85**	**24.11**	**25.48**	**6.85**	**5.95**	**6.4**
KNO_3 3%	10.15	10.23	10.19	12.7	12.53	12.62	31.25	32.34	31.79	24.12	22.17	23.14	5.35	5.17	5.26
Mean	9.13	9.13	9.13	11.06	11.06	11.06	26.25	26.25	26.25	18.92	18.92	18.92	4.25	4.25	4.25
C	10.29	10.08	10.18	13.31	13.05	13.18	32.32	31.6	31.96	23.24	22.35	22.79	5.49	5.31	5.4
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.065	0.104	0.147	0.081	0.129	0.182	0.206	0.326	0.462	0.135	0.213	0.302	0.035	0.056	0.08
SEd	0.093	0.147	0.208	0.115	0.182	0.258	0.292	0.462	0.653	0.191	0.302	0.427	0.05	0.08	0.113
Cd (p = 0.05)	0.195	0.309	0.437	0.242	0.384	0.543	0.614	0.971	1.373	0.401	0.635	0.898	0.106	0.168	0.238

releazed from the embryo hence stimulating mRNA and production of α-amylase (Blankenship 2021). α-Amylase helps in the hydrolysis of the starch during seed germination. It may also be responsible for the maintenance of requisite water potential, by providing solute sugars during the seed germination phase. The germination rate of 14–27 % was observed in *Leymus chinensis* when treated with GA_3 (Ma *et al*. 2018). Other germination parameters like mean germination time, mean germination rate, mean daily germination percentage, peak value, CV, CVG and germination index were also highest for the seeds primed with GA_3 at 60 ppm concentration for 3 hrs (Table 3). The decrease in germination time and increase in germination rate is observed in *Brassica napus* compared to control when treated with GA_3 (Zhu *et al.* 2021). The seed priming treatment increased the length of seedling than control. The maximum length of shoot, root and seedling was observed in the seeds primed with GA_3 at 60 ppm concentration for 3 hrs (Table 4). GA_3 treatment accelerates germination by secreting hydrolytic enzymes which helps in weakening the seed testa and speed up seed germination by extending the shoots and roots (Pradhan *et al.* 2022). The increased seed length after GA_3 treatment is the result of the activation of dormant embryos to perform cell

Table 7. Effect of seed priming using KNO# on, shoot length, root length, seedling length, vigor index I and vigor index II of *Vigna unguiculata*.

Priming agent	Shoot length (cm) Soaking hrs			Root length (cm) Soaking hrs			Seedling length (cm) Soaking hrs			Vigor index I Soaking duration in h (d)			Vigor index II Soaking duration in h (d)		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	14.7	14.5	14.6	8.2	7.5	7.9	22.9	22.5	22.7	1901	1823	1862	58	41	50
KNO_3 1%	16.6	15.7	16.2	10.3	9.8	10.1	26.9	23.8	25.4	2367	1975	2171	77	45	61
KNO_3 2%	**16.5**	**15.5**	**16**	**11.1**	**10.4**	**10.8**	**27.6**	**25.9**	**26.8**	**2466**	**2245**	**2355**	**82**	**69**	**76**
KNO_3 3%	16.1	14.2	15.2	9.8	8.6	9.2	25.9	22.8	24.4	2253	1915	2084	72	54	63
Mean	10.1	10.1	10.1	6.7	6.7	6.7	16.8	16.8	16.8	1327	1327	1327	27	27	27
C	14.8	14	14.4	9.2	8.6	8.9	24	22.4	23.2	2063	1857	1960	63	47	55
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.091	0.144	0.204	0.058	0.092	0.131	0.149	0.236	0.334	13.444	21.257	30.063	0.429	0.679	0.96057
SEd	0.129	0.204	0.289	0.082	0.131	0.185	0.211	0.334	0.472	19.012	30.062	42.514	0.607	0.96	1.3584
Cd (p = 0.05)	0.272	0.43	0.608	0.174	0.275	0.389	0.444	0.702	0.993	39.946	63.16	89.322	1.276	2.018	2.854

Table 8. Effect of seed priming using $ZnSO_4$ on water content imbibition rate, germination (%), mean germination time and mean germination rate of *Vigna unguiculata*.

Priming agent	Water content Soaking duration in h (d)			Imbition rate Soaking duration in h (d)			Germination % Soaking hrs			Mean germination time Soaking hrs			Mean germination rate Soaking hrs		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	12.85	13.1	12.98	0.9	1.1	1	81	79	80	4.92	4.75	4.84	0.25	0.26	0.255
$ZnSo_4$ 1%	14.78	13.77	14.28	1.05	1.08	1.065	85	85	85	4.23	4.42	4.32	0.238	0.228	0.233
$ZnSo_4$ 2%	**15.91**	**13.25**	**14.58**	**1.32**	**1.15**	**1.235**	**89**	**83**	**86**	**3.45**	**4.51**	**3.98**	**0.213**	**0.24**	**0.226**
$ZnSo_4$ 3%	12.04	13.8	12.92	0.95	1.131	1.04	85	83	84	4.57	4.04	4.3	0.222	0.251	0.236
Mean	11.12	10.78	10.95	0.844	0.892	0.868	76	76	76	5.4	5.4	5.4	0.28	0.28	0.28
C							83	81	82	4.51	4.62	4.57	0.24	0.252	0.246
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.095	0.151	0.213	0.007	0.012	0.017	0.43	0.68	0.961	0.027	0.042	0.06	0.001	0.002	0.003
SEd	0.132	0.209	0.296	0.01	0.017	0.024	0.608	0.961	1.36	0.038	0.06	0.085	0.002	0.003	0.004
Cd (p = 0.05)	0.284	0.449	0.635	0.023	0.036	0.052	1.277	2.02	2.857	0.08	0.126	0.179	0.004	0.006	0.009

division, elongation, and multiplication (Nedunchezhiyan *et al*. 2023). The proportion of viable seed in a sample is determined by seed vigour testing, which also evaluates the seed's capacity to develop healthy seedlings in unfavorable or subpar growth circumstances that are comparable to those that would arise in the field. Seed vigour test is essential for seeds stored under unfavourable conditions or seeds sourced from unauthorized sources. In the present study seed vigour index I and II was estimated. The results revealed that the seeds primed with GA_3 at 60 ppm for 3 hrs had the highest seed vigour. Okra seeds primed with GA_3 resulted in seed viability of 74.59% (Bereded Sheferie 2023). GA_3 treatment promotes cell division by promoting DNA replication, repair seed damage and increases ATP availability which all inturn increases seed viability (Junhaeng *et al*. 2015). A study done by Arun, *et al.* (2016) in cowpea shows that priming with GA_3 100 ppm reduced the time to 50% germination and mean germination time and increased the germination percentage in low vigour seeds of cowpea.

Effect of KNO_3

The role of potassium nitrate as seed priming agent to

Table 9. Standardization of bio priming using $ZnSO_4$ on mean daily germination, peak value, CV, CVG and germination index of *Vigna unguiculata*.

Priming agent	Mean daily germination % Soaking hrs			Peak value Soaking hrs			(CVt) Soaking hrs			(CVG) Soaking hrs			Germination index Soaking hrs		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	8.45	8.74	8.6	12.34	12.93	12.64	32.78	27.88	30.33	21.3	20.03	20.67	5.19	5.21	5.2
$ZnSo_4$ 1%	10.83	9.24	10.04	13.77	11.6	12.68	36.36	29.1	32.73	23.78	22.83	23.31	5.91	5.31	5.61
$ZnSo_4$ 2%	**11**	**10.33**	**10.67**	**14.8**	**13.2**	**14**	**39.26**	**34.1**	**36.68**	**25.85**	**22.34**	**24.1**	**6.54**	**5.32**	**5.93**
$ZnSo_4$ 3%	9.76	9.86	9.81	13.65	14.28	13.97	27.91	30.48	29.2	22.16	25.13	23.65	5.27	5.78	5.52
Mean	7.45	7.45	7.45	10.05	10.05	10.05	25.49	25.49	25.49	19.24	19.24	19.24	4.65	4.65	4.65
C	9.5	9.12	9.31	12.92	12.41	12.67	32.36	29.41	30.89	22.47	21.91	22.19	5.51	5.25	5.38
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.059	0.093	0.132	0.084	0.133	0.188	0.202	0.32	0.453	0.146	0.231	0.327	0.035	0.056	0.079
SEd	0.083	0.132	0.186	0.119	0.188	0.266	0.286	0.453	0.641	0.207	0.327	0.463	0.05	0.07	0.112
Cd (p = 0.05)	0.175	0.277	0.392	0.25	0.395	0.559	0.602	0.953	1.347	0.435	0.688	0.973	0.105	0.167	0.236

Table 10. Effect of seed priming using $ZnSO_4$ on, shoot length, root length, seedling length, vigor index I and vigor index II of *Vigna unguiculata*.

Priming agent	Shoot length (cm) Soaking hrs			Root length (cm) Soaking hrs			Seedling length (cm) Soaking hrs			Vigor index I Soaking duration in h (d)			Vigor index II Soaking duration in h (d)		
	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean	3	6	Mean
Hydro	15.5	14	14.8	8.5	8.1	8.3	24	22.1	23.05	1950	1756	1853	32	43	38
$ZnSo_4$ 1%	16.1	14.8	15.5	9.7	8.8	9.3	25.8	23.6	24.7	2205	2002	2104	74	49	62
$ZnSo_4$ 2%	**16.6**	**15.4**	**16**	**10.3**	**9.2**	**9.8**	**26.9**	**24.6**	**25.75**	**2406**	**2034**	**2220**	**108**	**72**	**90**
$ZnSo_4$ 3%	14.2	13.1	13.7	9.4	9.3	9.4	23.6	22.4	23	1995	1865	1930	66	46	56
Mean	10.1	10.1	10.1	6.7	6.7	6.7	16.8	16.8	16.8	1277	1277	1277	26	26	26
C	14.5	13.5	14	8.9	8.4	8.7	23.42	21.9	22.66	1967	1787	1877	61	47	54
	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T	D	T	D*T
SEm	0.089	0.141	0.199	0.054	0.086	0.122	0.144	0.227	0.32	12.817	20.265	28.66	0.522	0.825	1.168
SEd	0.126	0.199	0.282	0.077	0.122	0.173	0.203	0.322	0.455	18.125	28.659	40.53	0.738	1.168	1.651
Cd (p = 0.05)	0.265	0.419	0.593	0.162	0.257	0.364	0.427	0.676	0.956	38.082	60.212	85.154	1.552	2.454	3.47

promote has been known for long time. In the current investigation KNO_3 was used in three concentrations viz., 1%, 2%, 3% as a priming agent with no treatment as control. The imbibition rate of the seeds primed with 2% KNO_3 was the highest compared with the other concentrations studied (Table 5). The imbibition time was lower when the concentration was higher and soaking duration was long. This was in agreement with the results of study by Ruttanaruangboworn *et al.* (2017) in rice where imbibition rate was lower in higher concentration of KNO_3. The germination characters like germination percentage, mean germination time, mean germination rate, mean daily germination percentage and peak value of germination were highest when the seeds were primed with KNO_3 at 2% for 3 hrs. At 3% KNO_3 treatment the germination was the lowest (Table 6). Higher concentrations exert decreasing effects on seed germination by causing death of cells and ultimately result in loss of seed viability. These were against the findings of Ruttanaruangboworn *et al. (*2017) where the germination in rice was higher in the seeds primed with 1% KNO_3 than 2 % KNO_3 in rice. This suggests that there is toxic effect of KNO_3 due to ion accumulation in the embryo (Song *et al.* 2007). In accordance with our results, priming of *Paspalum vaginatum* seeds with KNO_3 had significant effects on germination. During the process of halo-priming with potassium nitrate (KNO_3), ions derived from potassium nitrate solutions gather within the seeds, consequently lowering water potential and enhancing water absorption Shim *et al.* (2008). The availability of nitrate during imbibition provides additional sources for protein synthesis to enhance germination while seed priming (Basra *et al.* 2005). The coefficient of germination and germination index were highest for the treatment with KNO_3 2 % for 3 hrs. 0.1% KNO_3 was regarded as the best treatment for parameters like CVG and germination index in Apple. Similar results was also observed in crops like *Citrullus colocynthis* (Saberi *et al.* 2011), *Foeniculum vulgare*, *Cuscuta epithymum* (Tavili *et al.* 2010). The decrease in ABA sensitivity of imbibed seeds may due to the effect of KNO_3 (Bethke *et al*. 2006). The highest shoot length, root length and seedling length was observed in the treatment of KNO_3 at 2%. Maximum seedling length was achieved in tomato seed primed with 0.75% KNO_3 (Moaaz Ali *et al.* 2020). Seedling vigour is the combined result of the emerged seeds under a wide range of biotic and abiotic stresses. Seedling vigour is a combined measure of seedling length, seedling fresh weight, and seedling dry weight (ISTA 2015). Seed vigor I and II were highest in the treatment of KNO_3 at 2% for 3 hrs. Similar results were found in corn when the seeds were primed done with 1% KNO_3 (Hadinezhad *et al.* 2014) (Table 7). Many studies revealed the effect of KNO_3 viz., increase in germination potential and seedling vigour in tomato at 50 mmol KNO_3 (Ebrahimi *et al.* 2014), increase in seedling vigor in wheat (Shu *et al.* 2016).

Table 11. Effect of seed priming using GA_3, KNO_3, $ZnSO_4$ on germination value of *Vigna unguiculata*.

Priming agent	Germination value Soaking hrs			Priming agent	Germination value Soaking hrs			Priming agent	Germination value Soaking hrs		
	3	6	Mean		3	6	Mean		3	6	Mean
Hydro	142.33	138.75	140.54	Hydro	129.31	129.73	129.52	Hydro	149.82	131.33	140.58
GA_3 20 ppm	152.33	155.75	154.04	KNO_3 1%	154.53	155.43	154.98	$ZnSo_4$ 1%	150.05	145.33	147.69
GA_3 40 ppm	162.66	152.45	157.56	**KNO_3 2%**	**156.93**	**154.93**	**155.93**	**$ZnSo_4$ 2%**	**154.43**	**148.23**	**151.33**
GA_3 60 ppm	**165.33**	**161.66**	**163.5**	KNO_3 3%	147.3	131.33	139.32	$ZnSo_4$ 3%	150.8	153.47	152.13
C	112.38	112.38	112.38	C	112.38	112.38	112.38	C	112.38	112.38	112.38
Mean	147.01	144.2	145.6	Mean	140.09	136.76	138.43	Mean	143.5	138.15	140.82
	D	T	D*T		D	T	D*T		D	T	D*T
SEm	0.88	1.392	1.969	SEm	0.872	1.379	1.95	SEm	0.906	1.433	2.027
SEd	1.245	1.968	2.784	SEd	1.233	1.95	2.758	SEd	1.282	2.027	2.866
Cd (p=0.05)	2.616	4.136	5.85	Cd (p=0.05)	2.591	4.098	5.795	Cd (p=0.05)	2.693	4.258	6.022

Effect of $ZnSO_4$

Zinc is plays an important role in germination as it is an important component of various enzymes (Shazia Anwer Bukhari *et al.* 2021). In the current investigation seeds of cowpea were primed with $ZnSO_4$ solution at 1, 2, 3% for 3 and 6 hrs. The water content and imbibition rate were the highest for the primed seeds 2% concentration for 3 hrs (Table 8). The germination parameters like germination percentage, mean germination time, mean germination rate, mean daily germination and peak value of germination were maximum for the seeds primed at 2% concentration for 3 hrs (Table 9). Seed priming increased the germination rate resulting which in turns aids in germination (Sajjan *et al.* 2017). This is due to the faster conversion of substances into energy by various physical and chemical process. Priming of seeds with $ZnSO_4$ either at 0.025 or 0.05% shown higher germination percentage and germination index than control (Raj *et al.* 2019). This result was against result of the present study in which germination index was the higher at the treatment $ZnSO_4$ at 2% than at 1%. Seed priming with 0.05 mM of $ZnSO_4$ recorded higher values for germination %, mean germination time (MGT), mean germination rate (MGR), coefficient of velocity of germination (CVG), germination rate index (GRI) (% / day), germination index (GI), shoot, root and seedling length in wheat (Singhal and Bose 2020). In the current investigation, seed priming with $ZnSO_4$ at 2% recorded the maximum values of growth parameters like shoot length, root length and seedling length, coefficient of velocity of germination and seed vigor. Priming the seeds with $ZnSo_4$ resulted in increased root and shoot length compared to unprimed seeds (Farooq *et al.* 2005) (Table 10).

Effect of hydropriming

The hydroprimed seeds performed better than unprimed seeds for each and every character studied. Many studies have reported that hydropriming of seeds improved the seed germination and seedling emergence of rice (Basra *et al.* 2005). Hydropriming of seeds of *Pisum sativum* for 12 hrs had a significant on its germination characters (Singh *et al.* 2017). (Table 11).

From the present study it can be clearly known that priming seeds with GA_3 at 60 ppm, KNO_3 at 2%, $ZnSO_4$ at 2% increases the seed germination parameters which in turn increases the yield.

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