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Effect of integrated nutrients management and drought mitigating strategies on yield, water use efficiency and soil fertility of rainfed chickpea (*Cicer arietinum*)

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ABSTRACT

A field experiment was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India) on sandy clay loam soil during winter season of 2012-13 and 2013-14 to find out the effect of integrated nutrients and drought mitigating strategies on productivity, water use efficiency and soil health of rainfed chickpea (*Cicer arietinum* L.). The result showed that the application of 100% RDF + 2% urea spray proved significantly superior to the 100% RDF+ 25% N (VC), 100% RDF + 5 kg Zn/ha and 100% RDF in terms of the number of pods/plant (51.41), seed pod (1.18), 100-seed weight (26.81 g), seed yield (1 200 kg/ha) and water use efficiency (13.36 kg/ha/mm) of chickpea and available nutrients in soils (187.06 kg/ha N, 22.66 kg/ha P_2O_5, 203.99 kg/ha K_2O, 18.20 kg/ha S and 0.66 mg/kg Zn soil) during both the years. Similarly, foliar spray of 2% KCl + 0.4% sodium selenite recorded maximum values of number of pods/plant (55.06), seeds/pod (1.14), 100-seed weight (26.16 g) and finally seed yield (1 159 kg/ha) of chickpea which was found comparable to 2% KCl during both the years. Maximum water use efficiency (12.93 kg/ha mm) and available soil nutrients (188.57 kg/ha N, 22.15 kg/ha P_2O_5, 204.03 kg/ha K_2O, 17.83 kg/ha S and 0.66 mg/kg Zn soil) were recorded highest under 2% KCl + 0.4% sodium selenite during both the years.

Key words: Chickpea, Drought mitigating practices, Integrated nutrients, Water use efficiency, Yield

Chickpea (*Cicer arietinum* L.) is the most important winter season grain legume in India, grown predominantly under rainfed conditions occupying 8.32 million hectares area and contributing 7.5 million tonnes to the national pulse basket with productivity of 912 kg/ha in 2011-12. Uttar Pradesh produced 0.72 million tonnes of chickpea with productivity of 1 248 kg/ha in 2011-12 (Directorate of Economics and Statistics, Department of Agriculture and Cooperation 2012). Farmers of the Eastern U.P. region normally overall grow this crop on residual soil moisture after harvest of *kharif* crops. If harvested rain water becomes available, they produce a good yield of chickpea either with presowing irrigation or life saving irrigation at critical stages of the crop. But under the present deficient rainfall situation, it becomes difficult to harvest a good crop of chickpea under nonavailability of harvested rain water, foliar feeding of important nutrients may play pivotal role in optimizing the crop productivity (Rathore *et al*. 2007). Foliar application of major or micro nutrients may be helpful in boosting the crop yield particularly under the deficient soil moisture (Kumar *et al.* 2008). Considering the importance of this fact the present investigation was conducted. The moisture stress condition prevailing during the season particularly at post-flowering period causes drastic reduction in grain yield of chickpea (Krishnamurthy *et al.* 2010). Therefore, to achieve better crop productivity under such conditions, proper nutrients management as well as suitable drought mitigating practices matching with the crop requirement may play an important role. The limited and erratic rainfall in the rainfed area makes chickpea vulnerable to experience moisture stress conditions during the later part of its growth, resulting in severe yield reduction. The low yield of chickpea is not only due to its cultivation on sub-marginal lands but also poor levels of nutrient management. In order to overcome this problem, soil has to be fertilized with different sources of nutrients. The combined application of organic manures and chemical fertilizers generally produces higher crop yields than when each is applied alone (Rajput and Kushwah 2005). Lack of adequate soil moisture in the seedbed is a major hindrance to the establishment of chickpea crop. This is because inadequate soil moisture can reduce seed germination, slow down seedling growth and diminish yield in rainfed crops (Sharma 1985). Therefore, it is urgently required to find out solutions to mitigate these drought effects in agriculture of the country by applying various drought mitigating practices. However, meager information is available on recommended dose of fertilizers, urea spray,

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vermicompost, micronutrients and combined use in many crops including chickpea. Therefore, the present experiment was carried out.

MATERIALS AND METHODS

A field experiment was conducted during winter season of 2012-13 and 2013-14 at the Research Farm, Institute of Agricultural Sciences, BHU, Varanasi, India ($25^0 18'$ N Latitude; $83^0 03'$ E longitude; altitude of 75.7 m ASL) in Northern Gangetic alluvial plains having sub-tropical climate. The rainfall received during the growing period of crop was 76.4 and 138.3 mm, respectively, during 2012-13 and 2013-14. The soil of the experimental plot was sandy clay loam (53% sand, 23.50% silt and 23.50% clay by Black 1967), poor in organic carbon (0.35%, Walkley and Black 1934), available nitrogen (193.60 kg/ha by Subbaiah and Asija, 1973) and sulphur (19.8 kg/ha by Chesnin and Yien 1950) and medium in available phosphorus (19.80 kg/ha Olsen's 1954) and available potassium (212.30 kg/ha, Jackson 1973). The level of zinc was below the critical limit (0.53 ppm, Lindsay and Norvell 1978). However, soil having optimum pH of 7.30 and EC (0.14 dS/m) during both the years of investigation. The experiment was laid-out in a three time replicated split plot design assigning four integrated nutrient management treatments, viz. 100 % RDF, 100% RDF + 2% urea spray, 100% RDF + 25% RDN (VC) and 100% RDF + 5kg Zn/ha in main plot through inorganic fertilizers and RDN represents recommended dose of nitrogen through vermicompost. Five drought mitigating strategies, viz. control, water spray, 2% KCl spray, 0.4% sodium selenite spray and 2% KCl + 0.4% sodium selenite applied twice at pre-flowering and pod formation stage in sub plots. The gross and net plot size were 22.5 m^2 (5.0 × 4.5 m^2) and 10.8 m^2 (4.0 × 2.7 m^2), respectively.

Nitrogen, phosphorus, potassium, sulphur and zinc fertilizers were applied just before sowing according to the treatment using urea (20 kg/ha), DAP (40 kg/ha), murate of potash (20 kg/ha), gypsum (20 kg/ha) and zinc oxide (5 kg/ha). As per treatment, entire dose of fertilizers were applied as basal placement (just before sowing the crop) 4-5 cm below the seed line. The required amount of 25% RDN (vermicompost @ 7 kg) containing N (3.0%), P (1.0%) and K (1.5%) as per the treatment were incorporated in the plots after preparing the layout and 2 days before sowing in to the soil during both the years. The chickpea cultivar Avarodhi was taken as a test crop. The crop was sown on 11 November (2012) and 14 November (2013) using a seed rate of 80 kg/ha with the help of spade. The optimum plant population was maintained by thinning and gap filling within a week after sowing to ensure the uniform plant population with spacing of 30 × 10 cm. Weeding practices were done at 30 and 45 DAS between the rows by dryland weeder. The crop was grown under rainfed conditions and only one life saving irrigation was applied from harvested water in farm pond to save the crop and maintain optimum soil moisture for plant growth. There was no serious incidence of any major pest or disease during period of crop growth. The observations were recorded at physiological maturity. Soil moisture estimation were made at pre-flowering and at harvest stage from samples collected at 0-15 , 15-30 and 30-60 cm depths and workout through thermo-gravimetric method as described by Dastane (1967). The moisture percentage by weight was then converted into depth of moisture (mm). Then, the water use efficiency (WUE = Y/ET) and available soil nutrients (method references mentioned above) were also recorded.

$$\text{Moisture content (mm)} = \frac{\text{Bulk density (g/cm}^3\text{)}}{100} \times \text{Depth of soil (mm)} \times \text{Moisture (\%) (by weight)}$$

RESULTS AND DISCUSSION

Effect of integrated nutrients and drought mitigating practices on chickpea

The basic vegetative phase had a significant role in shaping the reproductive organs, which is most important from point of view of obtaining high yield. Number of pods/plant is largely governed by the number of branches which increased with increasing nutrient levels (Devi *et al.* 2013), leading to increased number of pods/plant. With higher application of fertilizers, the process of tissue differentiation from stomatic to reproductive, meristematic activity and development of floral primordial might have been enhanced causing greater number of flowers which later developed in pods. In addition, under higher supply of nutrients, there might be more efficient translocation of photosynthates from leaves via stem to stalk site that is the pod and the seeds. This resulted in higher number of seeds, which on maturity became bold with higher 100- seed weight. The values of yield attributes namely number of pods/plant, seeds/pod, seed yield/pod and 100-seed weight (Table 1) were recorded under the treatments to find out the variation in yield response. The seed production mainly depends on yield attributes viz. number of pods/plant, number of seeds/pod and 100-seed weight. These attributes were favourably affected by fertilizer application. This envisages a direct role of nitrogen to seed growth and a guided help in minimizing osmotic imbalance present during final stage in seed filling (Rathore *et al*. 2007). On pooling of data, the number of pods/plant (51.41), seeds/pod (1.18), 100-seed weight (26.81 g) and seed yield (1 200 kg/ha) increased significantly with 100% RDF + 2% urea spray during both the years. This was the most dominant factor deciding the final yield. While 100% RDF + 2% urea spray was at par to 100% RDF + 25% RDN (VC) which might be due to the beneficial effect of vermicompost with mineral nutrients is envisaged by its greater and longer availability of nutrients as per the demand of the crop (Khanda and Mohapatra 2003).

Foliar spray of 2% KCl + 0.4% Sodium selenite was significantly superior to rest of the treatments during both the years of study. The second best treatment in order of magnitude was 2% KCl which proved significantly superior to rest of the three treatments in respect of yield attributes namely number of pods/plant (55.06), seeds/pod

Table 1 Yield, yield attributes and water use efficiency of chickpea as influenced by the treatments

Treatment	Pods/plant			Seeds/pod			Seed yield (kg/ha)			100-seed weight (g)			Water use efficiency (kg/ha/mm)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
Integrated nutrients management															
M_1	43.87	31.08	37.48	0.86	0.75	0.81	1083	799	941	24.92	23.77	24.34	10.51	8.85	9.68
M_2	53.44	49.38	51.41	1.26	1.09	1.18	1348	1051	1200	27.74	25.89	26.81	13.94	12.77	13.36
M_3	51.52	47.87	49.69	1.09	1.02	1.05	1319	1008	1164	27.59	25.84	26.72	13.29	11.99	12.64
M_4	47.97	43.00	45.48	1.02	0.86	0.94	1223	828	1026	26.08	24.24	25.16	12.19	9.65	10.92
SEm ±	0.69	0.65	0.55	0.05	0.07	0.05	9.12	13.84	8.34	0.11	0.02	0.06	0.09	0.15	0.09
CD(P=0.05)	2.40	2.25	1.89	0.18	0.23	0.18	31.57	47.91	28.87	0.39	0.07	0.21	0.30	0.52	0.30
Drought mitigating practices															
S_1	37.14	30.88	34.01	0.85	0.77	0.82	1170	832	1001	26.15	24.41	25.28	11.45	9.31	10.38
S_2	46.56	39.60	43.08	0.97	0.86	0.91	1206	883	1044	26.39	24.76	25.58	11.92	10.10	11.01
S_3	53.33	47.24	50.28	1.19	1.03	1.11	1278	969	1124	26.78	25.16	25.97	12.98	11.59	12.28
S_4	50.65	44.63	47.64	1.05	0.94	1.00	1243	925	1084	26.62	24.99	25.80	12.49	10.80	11.64
S_5	58.34	51.79	55.06	1.22	1.05	1.14	1321	997	1159	26.97	25.34	26.16	13.58	12.28	12.93
SEm ±	0.64	0.56	0.41	0.07	0.05	0.05	9.00	8.11	6.52	0.08	0.04	0.04	0.09	0.09	0.07
C D(P=0.05)	1.84	1.61	1.18	0.22	0.14	0.14	25.92	23.35	18.80	0.23	0.11	0.13	0.26	0.26	0.20

M_1- 100% RDF, M_2 - 100% RDF + 2% urea spray, M_3 - 100% RDF+ 25% N (VC), M_4 - 100% RDF + 5 kg Zn/ha. S_1- Control, S_2 -Water spray, S_3 - 2 % KCl spray, S_4 - 0.4% sodium selenite spray, S_5- 2 % KCl spray + 0.4% sodium selenite spray.

Table 2 Available soil nutrients as influenced by the treatments in rainfed chickpea

Treatment	Soil N (kg/ha)			Soil P (kg/ha)			Soil K (kg/ha)			Soil S (kg/ha)			Soil Zn (mg/kg soil)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
Integrated nutrients management															
M 1	183.45	173.67	178.56	20.75	16.45	18.60	202.85	194.52	198.68	14.96	12.11	13.54	0.37	0.31	0.34
M 2	190.78	183.34	187.06	24.81	20.51	22.66	208.15	199.82	203.99	19.62	16.78	18.20	0.56	0.75	0.66
M 3	190.42	182.27	186.34	23.72	19.42	21.57	206.80	198.47	202.64	18.59	15.75	17.17	0.51	0.64	0.58
M 4	189.41	180.05	184.73	23.04	18.74	20.89	205.54	197.21	201.38	16.65	13.81	15.23	0.81	0.78	0.80
SEm ±	0.17	0.49	0.26	0.32	0.32	0.32	0.13	0.12	0.09	0.024	0.02	0.02	0.01	0.01	0.01
CD (P=0.05)	0.60	1.70	0.91	0.99	1.12	1.10	0.44	0.46	0.30	0.084	0.08	0.08	0.02	0.04	0.02
Drought mitigating practices															
S1	181.90	173.55	177.73	21.41	17.11	19.26	203.92	195.58	199.75	15.70	12.86	14.28	0.51	0.54	0.53
S2	185.78	177.37	181.57	22.57	18.27	20.42	204.88	196.54	200.71	16.53	13.69	15.11	0.53	0.59	0.56
S3	191.25	182.73	186.99	23.93	19.63	21.78	206.58	198.25	202.42	18.41	15.57	16.99	0.59	0.65	0.62
S4	190.74	181.29	186.01	23.17	18.87	21.03	205.62	197.29	201.45	17.39	14.55	15.97	0.56	0.62	0.59
S5	192.91	184.24	188.57	24.30	20.00	22.15	208.20	199.87	204.03	19.25	16.40	17.83	0.61	0.71	0.66
SEm ±	0.16	0.50	0.26	0.23	0.24	0.23	0.07	0.08	0.07	0.05	0.05	0.05	0.01	0.01	0.01
CD (P=0.05)	0.45	1.44	0.74	0.64	0.67	0.67	0.20	0.21	0.21	0.14	0.15	0.15	0.02	0.02	0.02

M_1- 100% RDF, M_2 - 100% RDF + 2% urea spray, M_3 - 100% RDF+ 25% N (VC), M_4 - 100% RDF + 5 kg Zn/ha. S_1- Control, S_2 -Water spray, S_3 - 2 % KCl spray, S_4 - 0.4% sodium selenite spray, S_5- 2 % KCl spray + 0.4% sodium selenite spray.

(1.14), 100-seed weight (26.16 g) and finally seed yield (1159 kg/ha) (Table 1). While, it was at par with 2 % KCl for seeds/pod. This might be due to the increased starch accumulation in chloroplasts by Selenium (Pennanen and Hartikainen 2002). In addition potassium is also involved in photophosphorylation, transportation of photoassimilates from source tissues via the phloem to sink tissues, enzyme activation, turgor maintenance, and stress tolerance (Pettigrew 2008).

Effect of integrated nutrients and drought mitigating practices on water use efficiency of chickpea

Among the various integrated nutrients, application of 100% RDF + 2% urea spray recorded the highest values of water use efficiency as compared to other treatments. Under rainfed condition, foliar feeding of urea functions as nutrient supplementing as well as drought mitigating agent both. It observed that under the condition of deficient soil profile moisture, 2% foliar spray of urea resulted into yield compensation (Singh *et al.* 2010). Application of 100% RDF + 2% urea spray had the highest efficiency (13.36 kg/ha/mm) to utilize stored soil moisture followed by other treatments (Table 1). This was probably due to the effect of nutrients supplied by foliar spray which helped the plants attaining better growth and deep penetration of roots.

Foliar spray of 2% KCl + 0.4% Sodium selenite increased the water-use efficiency (12.93 kg/ha/mm) and it was significantly superior to rest of the treatments during both the years. The combined effect of potassium and selenium enhanced the water use efficiency of the crops by their osmo-regulatory and anti-oxidative mechanism. The results are in close conformity with the findings of Seppanen *et al.* (2003).

Effect of integrated nutrients and drought mitigating practices on available soil nutrients

Combined application of N, P, K and S along with foliar spray of N not only increased growth and yield but also enhanced soil nutrient availability too. Urea is one of the most widely used foliar N- fertilizers, characterized by its high leaf penetration rate and most plants can absorb rapidly and hydrolyze in the cytosol (Witte *et al.* 2002). Urea can also increase the level of storage N compounds, such as amino acids and proteins (Dong *et al.* 2004), thus foliar spray of urea could directly affect N metabolism under stressful conditions and therefore amino acids synthesis. Thus, it might be resulted in efficient utilization of nutrients and maximized their availability in soil. All these may lead to increased nutrients (N, P_2O_5, K_2O and S) availability of soil in the plots receiving combined application of 100% RDF + 2% urea spray fertilizers in the present investigation. The increase in the available N, P, K and S in soil after harvest of the crop was due to increased supply of nutrients accruing directly through inorganic fertilizers and that released through foliar spray of 2% urea (Gupta *et al.* 2011). While, application of 100% RDF + 5 kg Zn/ha resulted in increased availability of zinc in soil (Table 2). The results are in close agreement with the findings of Mortvedt (1991).

Pooled data revealed that foliar spray of 2% KCl + 0.4% Sodium selenite resulted in increased soil nutrient availability as compared to the control. While, it was at par with 2% KCl in respect of phosphorus availability. This might be due to better roots development and availability of adequate soil moisture because of higher moisture use efficiency which resulted into more binding of nutrients to the rhizosphere (Pettigrew 2008).

Thus, it is concluded that application of 100% RDF + 2% urea along with foliar spray of 2% KCl + 0.4% sodium selenite gave the maximum seed yield, higher water use efficiency and improves soil fertility status during both the years of investigation. Based on the above conclusions, it is recommended that application of recommended dose of fertilizers (20 kg N, 40 kg P_2O_5, 20 kg K_2O and 20 kg S/ha) plus 2% urea spray at pre-flowering and pod formation stages along with foliar spray of 2% KCl + 0.4% Sodium selenite should be practiced for improving soil fertility, water use efficiency and higher yield of rainfed chickpea in agroclimatic conditions of Varanasi region.

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