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Effect of drought mitigation strategies on yield and economics of chickpea (*Cicer arietinum* L.)

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Abstract
The field experiment was conducted during *rabi* season of 2018-19 at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P) to study the effect of different chemicals for drought mitigation on growth and yield of chickpea. The results revealed that Primary branches/plant was observed significantly higher in Pusa hydrogel 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development (T9). Yield attributes *viz*., pods per plant was recorded significantly superior under T_4: KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development (64.13) followed by FYM 5t/ha + seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha (T_8) while, test weight was noted marginally higher in T_5: Pusa hydrogel 2.5 kg/ha (208.3 g). Application of FYM 5 t/ha + Pusa hydrogel 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development spray (T_{10}) recorded significantly superior seed yield of chickpea (1805 kg/ha), which gave 218 kg (13.87%) higher with the next succeeding and statistically at par treatment $T_{9:}$ pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development (1795 kg/ha). However, straw yield was found significantly higher in FYM 5 t/ha + Pusa hydrogel @ 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development spray (3790 kg/ha) followed by pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development (3362 kg/ha). Gross returns was noted significantly greater in $T_{10:}$ FYM 5 t/ha + Pusa hydrogel 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development spray (Rs 87006/ha) followed by T_9 pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development (Rs 85734/ha) while, net returns was found significantly superior under $T_{9:}$ Pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development spray (₹ 59674/ha).

Keywords: Chickpea, drought mitigation, Seed hardening, FYM, seed yield, economics, $CaCl_2$, KH_2PO_4 pusa hydrogel

Introduction
Pulses in India have been considered as good source of protein, thus play a crucial role in healthy diets, sustainable food production and above all, in food security. India has appreciable 35% share in global area and production, is thus largest producer and consumer of pulses. The pulse production of India is 23.95 million tonnes during 2017-18 however, in order to ensure self-sufficiency, the pulses requirement in the country is projected at 39 million tonnes by the year 2050 which necessitates an annual growth rate of 2.14% (Anonymous, 2018). Among the pulses, chickpea (*Cicer arietimum* L.) is the third most important food legume grown in over 45 countries in all Continents of the World. In India, chickpea ranks first among the legumes in area occupying of 105.73 lakh hectare, production of 111 lakh tonnes and productivity of 1056 kg/ha (Anonymous, 2017-18) [2]. As usual, Madhya Pradesh has contributed a significant 34% of the total chickpea area and 41% of total chickpea production in the country, thereby ranking first both in area and production.

In India the average yield of chickpea is very low, which might be due to the cultivation of this crop on residual or conserved soil moisture in cool dry season and the moisture in the profile gradually recedes as the crop grows. As a consequence, plant experience progressively increasing degree of terminal moisture stress. Moisture stress is a major limiting factor in realizing crop productivity. It is known that Chickpea thrives well under drought prone conditions. Moisture stress and high temperature during early seedling and seed filling stages are the major constraints of its low productivity. It is an important factor affecting partitioning of biomass however, the influence of water deficit on distribution of assimilate depends on the stages of growth and relative sensitivity of various plant organs to water deficit. Nitrogen fixation, uptake and assimilation by leguminous plants are reduced due to reduction in leghemoglobin in nodule and number of nodules under moisture stress condition. Depending on the level of stress, legumes may suffer from grain yield loss to a larger extent than shoot biomass reduction.

Water deficit increases the plants dependency on remobilization for seed filling. The development of moisture stress leads to a wide range of change in plant processes like diversion of biomass to undesirable plant parts. There is an urgent need to identify suitable ameliorative measures to overcome of moisture stress and improve the productivity potential of chickpea under receding soil moisture conditions. However, there are certain avenues to induce drought tolerant technologies and conserving soil moisture condition *viz*. seed hardening technique which results in modifications in physiological and biochemical nature of seed so as to get the characters that are favour drought resistance. Pre-sowing seed hardening may be the result of extensive physiological induced by dehydration process. The inorganic salts like $NaCl_2$, Na_2SO_4, KCI, KH_2PO_4, $CaCl_2$ and $MgSO_4$; organic acids like succinic acid, CCC and auxins are used as pre-hardening agents. Hydrogel is a synthetic polymer used as soil amendment. Hydrogel is insoluble, hydrophilic in nature and can absorb large quantity of water. The capacity of the hydrogel to absorb and retain water is as much as 80-180 times its original volume while, on weight basis it can absorb as high as 400 times its original weight. The use of FYM (Farm Yard Manure) for raising crop is an age-old practice. It is not only supplies organic matter with major nutrients in small quantities but also enriches the soil with several micronutrients. Keeping in view the above facts, the present study was designed to assess the effect of drought mitigation strategies on productivity of chickpea.

Materials and Methods

An experiment was conducted at Agriculture farm of Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P) during *rabi* season of 2018-19. The farm is situated under Kymore Plateau of Eastern Madhya Pradesh (25^0 10′ N latitude, 80^0 32′ E longitude and 190-210 meter above mean sea level). The soil of experimental field was sandy loam with neutral p^H (7.46), low organic carbon (0.33%) and available nitrogen (182.16 kg/ha) and medium in available phosphorus (18.11 kg/ha) and available potassium (218 kg/ha). The experiment was laid out in randomized block design with three replications. There are ten treatments *viz*., T_1: Control, T_2: Seed hardening with 2% $CaCl_2$, T_3: FYM @ 5t/ha, T_4: KH_2PO_4 @ 2% at flower initiation + KNO_3 @ 2% at pod development, T_5: Pusa hydrogel @ 2.5 kg/ha, T_6: Seed hardening with 2% $CaCl_2$ + Pusa hydrogel @ 2.5 kg/ha, T_7: FYM @ 5 t/ha + Pusa hydrogel @ 2.5 kg/ha, T_8: FYM @ 5t/ha + Seed hardening with 2% $CaCl_2$ + Pusa hydrogel @ 2.5 kg/ha, T_9: Pusa hydrogel @ 2.5 kg/ha + KH_2PO_4 @ 2% at flower initiation + KNO_3 @ 2% at pod development spray, T_{10}: FYM @ 5t/ha + Pusa hydrogel @ 2.5 kg/ha + KH_2PO_4 @ 2% at flower initiation + KNO_3 @ 2% at pod development spray. The chickpea variety RVG 203 was sown on November 07, 2017 and November 18, 2018 at a row spacing of 30 cm apart using seed rate 100 kg/ha. The plant to plant spacing was maintained 05 cm by thinning at 20 DAS.

The recommended dose of fertilizers for chickpea was 20:60:20 kg N: P_2O_5: K_2O per ha, which were provided through DAP and muriate of potash as basal. Various drought mitigation treatments were applied as per the treatment. Required quantity of well decomposed FYM was applied and incorporated in to the soil as per prescribed plots before sowing. All the other agronomic practices were done uniformly to all the treatments. Weeds of experimental plot were controlled by hand weeding at 30 days after sowing. Insect pest was controlled by application of Dimethoate @ 2ml/lit water of pod formation stage. All the observation of experiment was recorded as per standard procedure. The economics of experimental was evaluated as per prevailing prices of local market. The crop was harvested on March 28, 2018. The important parameters were recorded at appropriate time as per standard procedure. The economics of treatment was calculated as per prevailing market price of the area. The experimental data was statistically analysed by Gomez and Gomez (1984). The treatment differences were tested by using "F" test and critical differences at 5% probability.

Results and Discussion

Effect on growth

Growth parameter *viz*., plant height was recorded significantly higher under treatment T_4: KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development (23.67 cm) at 60 days after sowing. However at same stage, the significantly more leaves per plant were observed in T_8: FYM 5t/ha + seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha (52.93). Plant dry weight and tertiary branches/ plant were noted superior in T5: Pusa hydrogel 2.5 kg/ha. Primary branches/plant was observed significantly greater in T9: Pusa hydrogel 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development followed by T8: FYM 5t/ha + seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha. While, secondary branches was recorded significantly more in T_6: Seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha. It might be explained due to more availability and uptake of nutrients in crop plant by use of these materials or organic manure, which increased the growth parameters. Similar effects were also observed by Islam *et al.* (2011) [4] in maize yield with application of super absorbent polymer. Gautam (2017) [3] reported incremental effects of Pusa hydrogel on crop growth. Similar effects of $CaCl_2$ and KH_2PO_4 were also reported by Ramesh (2004) [14]. Manjunath and Dhanoji (2011) [9] found significantly higher morpho-physiological traits like plant height, number of leaf lets, leaf dry matter and total dry matter accumulation and leaf area/plant with seed hardening.

Effect on yield attributes

Yield attributes *viz*., pods per plant was recorded significantly superior under T_4: KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development (64.13) followed by T_8: FYM 5t/ha + seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha. Number of seeds per pod was recorded numerically higher under T_2: Seed hardening with 2% $CaCl_2$ (2.00) followed by T_5: Pusa hydrogel 2.5 kg/ha. However, test weight was noted marginally higher in T_5: Pusa hydrogel 2.5 kg/ha (208.3 g) followed by T_2: Seed hardening with 2% $CaCl_2$ (206 g). The higher yield attributes could be ascribed due to superior growth parameters of drought mitigation treatment. This might be due to the property of polymers to aggregate and stabilize soils, compact erosion, improve percolation and absorbing soil water. These findings are in agreement with the results of various experiments conducted by Khadem *et al.* (2010) [6]. The findings of Anbu *et al.* (2001) [1] also supported that the potassium nitrate (KNO_3) increased the yield parameters. Seed hardening with $CaCl_2$ was also advocated by Prajapati *et al.* (2017) [13].

Effect on yield

The drought mitigation treatment FYM @ 5 t/ha + Pusa hydrogel 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development ($T_{10)}$ recoded significantly superior seed yield of chickpea (1805 kg/ha) which gave 218 kg

(13.87%) higher over control (Table 2). The straw yield was observed significantly higher with the T_{10}: FYM 5 t/ha + Pusa hydrogel 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development (3790 kg/ha). This could be associated with higher value of growth characters and yield attributes (Table 2). The possible reasons for treatments effect on seed yield due to save water as well as water soluble nutrients up to 40 to 60%. An increase in yield might be due to sufficient availability of water and indirectly nutrients supplied by the super absorbent polymer to the plants under water stress condition which in turn lead to better translocation of water, nutrients and photosynthesis and finally better plants stand and yield. Significant increase in seed yield were also be reported by Gautam (2017) [3]. Keshavarz *et al.* (2012) [7] reported that the incorporation of super absorbent polymer gave significantly higher seed yield. Li *et al.* (2004) [8] also proved that KH_2PO_4 increased seed yield of chickpea because it mobilizes organic P in both hydroponic and soil cultures, leading to an inter specific facilitation in utilization of organic P. Jai Bharti and Malik (2013) [5] also proved that the use of KNO_3 positively influences the seed yield. Prabhu *et al.* (2018) [12] also confirms the findings of the experiment. Manjunath and Dhanoji (2011) [9] also found that the seed hardening with chemicals like $CaCl_2$ recoded higher growth and resulted in to the greater straw yield.

Table 1: Effect of different drought mitigation treatments on growth of chickpea

Treatment	Plant height (cm) at harvest	Number of leaves/plant	Dry wt./plant (g)	Number of branches/plant		
				Primary branches	Secondary branches	Tertiary branches
T_1: Control	18.20	40.67	1.83	3.43	7.00	3.20
T_2: Seed hardening with 2% $CaCl_2$	20.80	42.73	2.27	3.43	7.67	3.00
T_3: FYM 5t/ha	21.67	51.80	1.87	3.80	7.53	3.27
T_4: KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	23.67	43.87	2.01	3.60	7.20	3.27
T_5: Pusa hydrogel 2.5 kg/ha	21.60	41.53	2.41	4.00	7.27	3.47
T_6: Seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha	22.87	47.67	2.11	4.00	8.33	3.27
T_7: FYM 5 t/ha + Pusa hydrogel 2.5 kg/ha	21.93	43.73	2.40	3.67	8.07	3.20
T_8: FYM 5t/ha + Seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha	21.53	52.93	2.01	4.47	8.00	3.27
T_9: Pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	21.60	43.00	2.12	4.60	8.03	3.07
T_{10}: FYM 5t/ha + Pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	21.47	44.20	2.16	4.33	7.93	3.27
SEm ±	0.89	2.37	0.12	0.20	0.26	0.14
CD (P=0.05)	2.64	7.03	0.36	0.60	0.77	NS

Table 2: Effect of different drought mitigation treatments on yield attributes and yield of chickpea.

Treatments	Yield attributes			Grain yield (kg/ha)	Straw yield (kg/ha)
	Pods/plant	Seeds/pod	Test weight (g)		
T_1: Control	29.87	1.78	201.0	1587	2612
T_2: Seed hardening with 2% $CaCl_2$	36.00	2.00	206.0	1667	3133
T_3: FYM 5t/ha	57.67	1.85	203.3	1699	3220
T_4: KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	64.13	1.87	197.7	1672	2708
T_5: Pusa hydrogel 2.5 kg/ha	53.13	1.93	208.3	1775	3301
T_6: Seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha	62.07	1.87	200.7	1731	3300
T_7: FYM 5 t/ha + Pusa hydrogel 2.5 kg/ha	52.13	1.88	201.7	1729	3326
T_8: FYM 5t/ha + Seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha	62.80	1.85	200.0	1775	3301
T_9: Pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	51.40	1.83	204.3	1795	3362
T_{10}: FYM 5t/ha + Pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	62.87	1.88	202.3	1805	3790
SEm ±	7.07	0.13	4.37	42.3	193
CD(P=0.05)	21.00	NS	NS	125	575

Table 3: Effect of different drought mitigation treatments on economics of chickpea.

Treatments	Cultivation of cost (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B: C ratio
T_1: Control	22101	75081	52979	3.39
T_2: Seed hardening with 2% $CaCl_2$	22235	79644	57408	3.58
T_3: FYM 5t/ha	28354	81226	52872	2.86
T_4: KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	23497	78998	55501	3.36
T_5: Pusa hydrogel 2.5 kg/ha	25074	84732	59657	3.37
T_6: Seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha	24798	82778	57980	3.33
T_7: FYM 5 t/ha + Pusa hydrogel 2.5 kg/ha	30916	82728	51811	2.67
T_8: FYM 5t/ha + Seed hardening with 2% $CaCl_2$ + Pusa hydrogel 2.5 kg/ha	31050	84702	53652	2.72
T_9: Pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	26059	85734	59674	3.29

T_{10}: FYM 5t/ha + Pusa hydrogel 2.5 kg/ha + KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development	32312	87000	54687	2.69
SEm ±	-	1938.8	1808	0.07
CD (P=0.05)	-	5759	5373	0.21

Effect of economics

Gross monetary returns was significantly higher under the treatment T_{10}: FYM @ 5t/ha + Pusa hydrogel 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development spray (₹ 87000 per ha). While, highest net monetary returns of ₹ 59674 per ha was recorded under Pusa hydrogel 2.5 kg/ha + 2% KH_2PO_4 at flower initiation + 2% KNO_3 at pod development spray (T_9). This could be associated with higher gross returns with lower cost of cultivation. In other words, these may be attributed to less increase in gross income than increase in cost under different drought mitigation treatments. Panda *et al.* (2017) [10] also confirms the findings of the experiment. However, the B:C ratio was found maximum of 3.58% in treatment T_2: Seed hardening with 2% $CaCl_2$. It was because of comparatively least cost of cultivation with moderate gross returns. Patil *et al.* (2014) [11] also found that the seed hardening with $CaCl_2$ (2%) recorded highest benefit cost ratio.

Conclusion

Thus, it can be concluded that the use of Pusa hydrogel 2.5 kg/ha with spary of KH_2PO_4 2% at flower initiation + KNO_3 2% at pod development was found the best treatment for getting higher productivity and profitability under prevailing climatic and soil conditions of Eastern Madhya Pradesh.

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