Influence of different levels of hydrogel on root nodulation in Chickpea (*Cicer arietinum* L.)

Abstract

This study investigated the impact of varying levels of hydrogel on the root nodules of Chickpea (Cicer arietinum L.) during Rabi seasons of 2019-20 and 2021-22 at the Department of Biological Sciences, Sam Higginbottom Institute of Agriculture, Technology, and Sciences, (U.P). The experimental design was a randomized block design with four levels of hydrogel (25%, 50%, 75% and 100%) and two levels of irrigation (one irrigation and two irrigation) and all treatments replicated thrice. Observations on the number of nodules per plant, active nodules, and inactive nodules were recorded at 30, 60, and 90 days after sowing (DAS) and at maturity and analysed using Fisher's ANOVA. The results indicated that hydrogel application significantly affected nodule formation at all growth stages across both years. The highest number of nodules, active nodules, and inactive nodules were recorded in treatment T_{10} (2 irrigations + 100% hydrogel), followed by T_9 (2 irrigations + 75% hydrogel), in both years. The enhanced nodule formation with hydrogel application was attributed to improved water availability to the roots during periods of water scarcity, highlighting hydrogel's role in optimizing nitrogen availability and promoting chickpea growth, which is crucial for enhancing soil fertility.

Introduction

Being a tropical country, India has seen a variety of changes in weather patterns and a rise in temperature resulted of change in climate and global warming. Increased transpiration caused by these changes reduces soil water levels, which has an impact on agricultural productivity. Water is one of necessary material for a plant to develop and advance (Rijsberman, 2008). In agriculture, irrigation and rainfall are the two primary water sources. 65% of the food produced globally comes from crops that are grown using irrigation, while the remaining 35% comes from rain-fed crops. Irrigation covers just 17% of all planted land. (Rosegrant, 2002 and Hanjra, 2010). As a result, the majority of land in agriculture is dependent on natural precipitation. Thus, an unprecedented drought is occurring in many of the world's food producing regions as a resulted of variation in the global rain pattern and a rise in local temperature. (FAO, 2008).Chickpeas possess deeply penetrating roots that enable them to access and utilize the limited moisture available in the soil, making them valuable for improving soil fertility (Tripathi et al., 2015). However, the challenges posed by salinized soils underscore the need for developing more resilient rhizobial inoculants that can thrive in such conditions, thereby enhancing the efficiency of nitrogen fixation and ultimately contributing to sustainable agriculture in saline environments.

Nitrogen fixation of leguminous plant is an important aspect of sustainable agriculture by which the atmospheric N_2 is converted to ammonia with the aid of a key enzyme called nitrogenase (Udvardi and Poole, 2013, Oldroyd *et al.*, 2011). It is achieved by bacteria inside the cells of *de novo* formed organs, the nodules, which usually develop on roots of various leguminous plants. This process is resulted from the complex interaction between the host plant and rhizobia.The chickpea, like other legumes, is important for environmentally friendly and sustainable farming. It may form a symbiotic relationship with rhizobia that can convert atmospheric nitrogen into ammonia that plants can directly absorb, increasing the productivity of this crop and succeeding cereal crops and enhancing soil fertility by fixing nitrogen at rates of up to 140 kg/ha/year (Flowers *et al.*, 2010), decreases the need of chemical fertilisers greatly, which lowers the amount of greenhouse gas emissions and water pollution per hectare each year (De la Pena and Pueyo, 2012). By boosting the synthesis of phytohormones and mineral absorption, several rhizobial strains have been shown to be able to stimulate plant growth and development (Karthik *et al.*, 2017). Chickpea is regarded as a host that restricts nodulation (Rivas *et al*., 2007; Laranjo *et al*., 2008; Suneja *et al*., 2016).The availability of nitrogen in agriculture has a significant impact on both output and product quality. In the natural world, plants either assimilate nitrate and ammonium or get nitrogen from di-nitrogen by collaborating with bacteria that fix nitrogen. The most significant symbiosis in terms of biological nitrogen fixation is between legumes and rhizobia, which together produce roughly 200 million tonnes of nitrogen annually (Graham and Vance, 2003; Peoples *et al*., 2009).The bacterial microsymbionts enter individual plant cells and settle in compartments encircled by a plant membrane to form a symbiosis necessary for nodulation (Jens Stougaard, 2000).Although the symbiotic nitrogen (N) fixation between legumes and Rhizobium is a crucial biological characteristic and the cornerstone of increasing soil fertility, there are currently few efficient rhizobial inoculants that can adapt to salinized soils. Previous research has demonstrated that drought and salt stress significantly reduced plant biomass accumulation (root and shoot), nodule growth, nitrogenase activity, and chickpea production (Garg and Baher, 2013; Egamberdieva*et al*., 2014). Due to their deeply penetrating roots, which allow them to make use of the scarce moisture that is available; chickpeas can improve the fertility of the soil (Tripathi *et al*., 2015).

Material and methods:

The field experiment of present investigation entitled "Impact of different levels of hydrogel on root nodules of Chickpea (*Cicer arietinum* L.)" was conducted during "rabi season" 2019-20 and 2021-22 under Department of Biological Sciences, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad (U.P).The climate of the experimental site is characterised by semi-arid type with hot and dry summer from April to June, hot and humid from July to September and cold winter from November to January. The experiment was conducted by the randomised block design with combinations of four level of hydrogel and two level of irrigation i.e. T_0 (3 irrigation),T_1(1 irrigatin)T_2(1 irrigation + 25% hydrogel)T_3 (1 irrigation + 50% hydrogel) , T_4 (1 irrigation + 75% hydrogel), T_5 (1 irrigation + 100% hydrogel), T_6(2 irrigatin) T_7 (2 irrigation + 25% hydrogel), T_8 (2 irrigation + 50% hydrogel), T_9 (2 irrigation + 75% hydrogel), T_{10} (2 irrigation + 100% hydrogel) are replicated thrice.During the crop growth period, the following observations were recorded time to time.Number of nodules/plants: After digging out three plants from randomly in each plot, the number of nodules were counted at regular intervals of 30, 60, 90 DAS and at maturity.Active nodules:Active nodules were counted on the basis of colour of the nodules.Inactive nodules:Inactive nodules were counted by subtracting Active nodules from Total number of nodules. Fisher's ANOVA technique and least significance difference (LSD) test at 5% probability level were used to compare differences among treatment means.

Result and discussion:

Application of Hydrogel to soil for cultivation of many crops under water scarce areas is proven beneficial. Many parts of studied area have water scarcity, hence present experimentation was conducted to assess the growth and yield performance of Chickpea (*Cicer arietinum* L.). The result has been presented and graphically illustrated using table and graph.The effect of application of hydrogel was found to be significant at 30DAS, 60 DAS, 90 DAS and at maturity in both the years. The maximum no. of Nodules 24.82, 32.37, 25.0 and24.5were recorded in treatment T_{10}in the year 2020, 2021and in pooled respectively and followed by treatment combination T_9 which is at par and recorded No. of Nodules in both the years respectively.

The effect of application of hydrogel on No. of Active Nodules was found to be significant at 30DAS, 60 DAS, 90 DAS and at maturity in both the years. The maximum No. of Active Nodules 22.52, 30:20.13:19 was recorded in treatment T_{10} in the year 2020, 2021and in pooled respectively and followed by treatment combination T_9 which is at par and recorded No. of Active Nodules in both the years respectively.

The effect of application of hydrogel on No. of Inactive Nodules was found significant at 30DAS, 60 DAS, 90 DAS and at maturity in both the years. The maximum No. of Inactive Nodules 3.52, 5.23, 9.17 and 7.82 was recorded in treatment T_{10}in the year 2020, 2021and in pooled respectively and followed by treatment combination T_9 which is at par and recorded No. of Inactive Nodules in both the years respectively.

This may due to the availability of water to the roots through hydrogel during water scarcity to the plants. Theavailability of nitrogen in agriculture has a significant impact on both output and product quality (Graham and Vance, 2003; Peoples *et al*., 2009).Chickpeas possess deeply penetrating roots that enable them to access and utilize the limited moisture available in the soil, making them valuable for improving soil fertility (Tripathi *et al*., 2015).

Table1.Influence of different levels of hydrogel on root nodules of Chickpea (*Cicer arietinum* L.)

	No. of nodules (Nos)				No. of active nodules (Nos)				No. of inactive nodules (Nos)			
Treatments	**30DAS**	**60DAS**	**90DAS**	**At harvest**	**30DAS**	**60DAS**	**90DAS**	**At harvest**	**30DAS**	**60DAS**	**90DAS**	**At harvest**
T_0	21.12	26.23	23.13	21.77	19.42	24.37	17.35	14.9	1.7	1.85	5.77	6.82
T_1	13.6	18.27	14.83	14.37	10.08	16.4	7.45	6.67	3.52	1.88	7.38	7.68
T_2	13.47	19.4	14.3	14	10.92	18.5	8.1	7.27	2.55	0.93	6.2	6.72
T_3	13.73	20.2	14.9	14.5	11.45	18.63	8.33	7.67	2.28	1.58	6.55	6.82
T_4	13.2	20.4	14.5	13.8	11.72	18.13	8.7	8.13	1.48	2.28	5.8	5.62
T_5	14.13	20.73	15.17	14.63	12.18	17.2	9.2	8.7	1.95	3.53	5.97	5.92
T_6	14.93	24.33	16.47	16.2	12.83	19.13	9.23	8.35	2.1	5.23	7.23	7.82
T_7	20.93	24.3	19.37	19.7	17.45	20.2	10.2	9.57	3.48	4.12	9.17	10.1
T_8	24.18	30.33	24.13	23	20.8	27.4	18.23	17.3	3.38	2.95	5.88	5.7
T_9	23.25	31.03	24.53	23.7	21.4	28.93	19.18	17.52	1.85	2.1	5.32	6.17
T_{10}	24.82	32.37	25.0	24.5	22.52	30.0	20.13	19.0	2.3	2.37	4.87	5.47
C.D.	0.91	2.45	1.91	2	0.43	1.77	0.19	0.93	0.97	1.49	1.98	2.2
SE(m)	0.31	0.82	0.64	0.67	0.15	0.6	0.06	0.31	0.33	0.5	0.67	0.74
SE(d)	0.44	1.17	0.91	0.95	0.21	0.84	0.09	0.44	0.46	0.71	0.94	1.05
C.V.	2.97	5.87	5.94	6.42	1.62	4.75	0.88	4.74	23.3	33.07	18.14	18.89

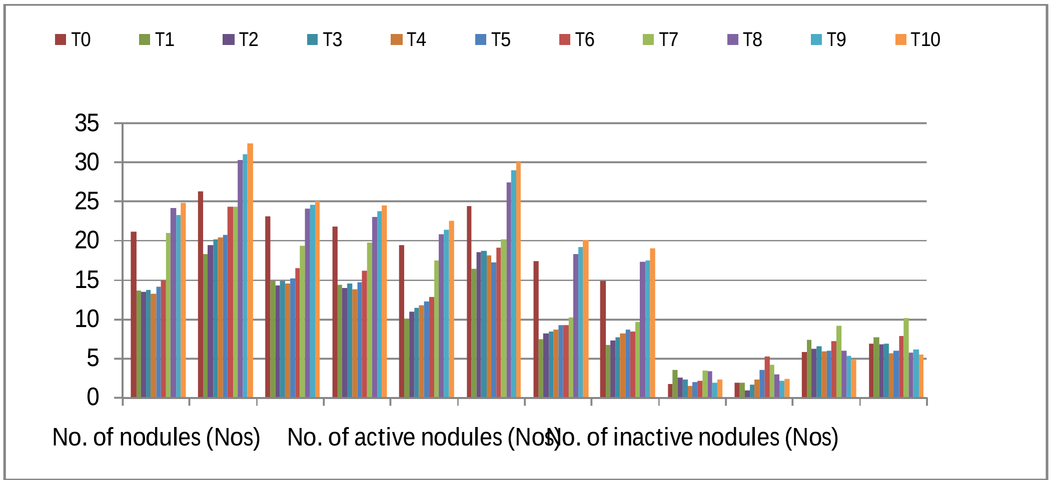

Fig. 1Influence of different levels of hydrogel on root nodules of Chickpea (*Cicer arietinum* L.)

Conclusion

The results of present study concluded that hydrogel application significantly affected nodule formation at all growth stages across both years. The highest number of nodules, active nodules, and inactive nodules were recorded in treatment T_{10} (2 irrigations + 100% hydrogel), followed by T_9 (2 irrigations + 75% hydrogel), in both years. The enhanced nodule formation with hydrogel application was attributed to improved water availability to the roots during periods of water scarcity, highlighting hydrogel's role in optimizing nitrogen availability and promoting chickpea growth, which is crucial for enhancing soil fertility.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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