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Evaluation of water retaining granules on winter maize (*Zea mays* L.) under supplemental irrigation

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Abstract
A field experiment was conducted at Bihar Agricultural University farm, Sabour, during *rabi* season 2011-12 and 2012-13 to evaluate the effect of sources and doses of hydrogel on growth, yield, root characteristics and economics of winter maize. The experiment comprised of two sources of hydrogel i.e. Stockosorb and Pusa gel in main plot and their application doses *viz.*, Control (No hydrogel), 50% hydrogel dose, 75% hydrogel dose, 100% hydrogel dose (20 kg/ha), 125% hydrogel dose and 150% hydrogel dose in sub plots laid out in split plot design with three replications. Results indicated that sources of hydrogel did not affect growth parameters significantly, however, they were significantly higher by hydrogel doses up to 150%. Plant height did not vary significantly due to hydrogel sources. Pusa gel was found superior over Stockosorb. Among hydrogel doses, 150% gel dose recorded maximum plant height (203.5 cm) as compared to control and was at par with 125% dose. At 90 DAS, Stockosorb was noted for higher LAI than Pusa gel. However, difference between gel sources was non-significant. Among hydrogel doses, 100%, 125% and 150% were on par with each other at 90 DAS and 125 DAS. Lowest LAI was recorded in control in both the time intervals. All the yield attributes were significantly influenced by gel sources except 1000-grain weight, however, they were significantly differed by hydrogel doses. Highest grain yield (81.7 q/ha) was recorded under 150% gel dose which was 2.1% higher than those of 125% gel dose, respectively, however, application of 100% and 125% dose differed significantly among each other. Recommended hydrogel dose recorded 3.3%, 10.6% and 29.2% higher grain yield over 75%, 50% gel dose and control, respectively. Stover yield was significantly highest under 150% gel dose which was superior over rest of the gel doses except 100% and 125% gel dose. Stone yield was recorded maximum under 150% gel dose being at par with 125% gel dose and was significantly higher over rest of the gel doses. Number of rootlets and root dry weight was found highest at 150% gel dose. Recommended dose of hydrogel at 20 kg/ha recorded Rs. 3,332/ha higher net return than control.

Keywords: Dose of hydrogel, maize, source of hydrogel and water retaining granules.

Introduction

Maize *(Zea mays* L.*)* is the third most important cereal in India after rice and wheat. India contributes about 3% towards total world maize production. It is versatile cereal grown for human food, poultry feed and fodder for livestock. In Bihar, maize productivity is 27.76 quintals ha^{-1} (Fertilizers Statistics, 2011). Due to more area expansion under maize, it has state productivity more than national average due to its high production potential in *rabi* season (8-10 tonnes ha^{-1}) and less incidence of insect pest and diseases.

Water, life saving natural resource for crop, influences photosynthesis, respiration, absorption and translocation of nutrients. Due to limited availability of irrigation water in India, it is important to increase irrigation efficiency and water productivity and to exploit existing water potential by reducing losses of water and ensuring better living condition for growth. Super absorbent polymer has great potential to exploit existing water in soil for the crop by increasing their production. It is water retaining, cross-linked hydrophilic, biodegradable amorphous polymer which can absorb and retain water 400 times of its original weight and make 95% of stored water available for crop absorption (Johnson and Veltkamp, 1985). Actually, polymer has capability to enable the crop to utilize water over extended time. When polymer is mixed with soil, it forms amorphous gelatinous mass on hydration and is capable of absorption and desorption over long period in soil.

Johnson (1984) reported that use of hydrogels increased available moisture in root zone, implying longer intervals between irrigations. Effect of hydrogel is affected if they are allowed to dry out and irrigation is important for longevity of hydrogels. Improvement in seed germination, crop establishment and growth will be consequence that will help to ensure uniform and healthy crop stand to achieve high crop yield.

Due to considerable volume reduction of hydrogel as water is released to the crop, hydrogel creates within soil, free pore volume offering additional space for air and water infiltration, storage and root growth. Large quantity of water retained by polymer provides available water to the crop which facilitates better growth. It reduces irrigation amount from 100 to 85% of crop water requirement and increases crop yield (El-Hady *et al*., 2006 It performs its wetting/drying cycle over longer period, maintaining its high swelling and releasing capacity against soil pressure. Its cultivation may be more profitable by decreasing water demand and irrigation frequency. Major question in supplemental irrigation revolves around how best we can utilize limited irrigation water? Keeping the issues, the present investigation was conducted to evaluate super absorbent polymer in maize.

Materials and methods

A field experiment was conducted on winter maize in Bihar Agricultural University farm, Sabour during *rabi* season of 2011-12 and 2012-13. The experiment was laid out in split plot design with three replications keeping sources of hydrogel *viz*., Stockosorb® (G_1) and Pusa gel (G_2) in main plot and their application doses *viz*., D_1- Control (No hydrogel), D_2- 50% dose of hydrogel, D_3- 75% dose of hydrogel, D_4- 100% dose of hydrogel (20 kg/ha), D_5- 125% dose of hydrogel and D_6- 150% dose of hydrogel in sub plots. Plot size is about 4 m x 3.6 m= 14.0 square meter. Soil of the experiment was non saline EC 0.19 dS/m, neutral pH 7.3, low in organic carbon 0.48% and available nitrogen 117.1 kg/ha and medium in available phosphorus 34.2 kg/ha and potassium 187.8 kg/ha. Cumulative rainfall during November to May for both the years 2011-12 and 2012-13 was 61.5 and 268.6 mm, respectively. Sowing of maize '30V92' at 60 x 20 cm apart was done on mid-November just after ploughing followed by harrowing and pulverized with tractor drawn rotavator. Prior to sowing, half dose of urea and full dose of DAP and MOP fertilizer was applied as basal and remaining urea was top dressed at knee high and tasseling stage. Three irrigations were given to provide proper moisture as per need of crop.

Observations were recorded on plant height and leaf area index, grain & stover/stone yield and yield attributes of the crop. Economics was worked out in terms of net return and B:C ratio. Data collected was analyzed following the statistical procedure described by Gomez and Gomez (1984). The level of significance used in 'F' and't' tests was P=0.05.

Results and discussion

Effect of hydrogel on growth parameters

Sources of hydrogel did not affect growth parameters significantly in maize. Growth parameters were significantly higher by application of hydrogel doses up to 150%.

Plant height

Plant height at harvest was not significantly varied due to hydrogel sources (Table 1), however, Pusa gel was superior over stockosorb. Hydrogel doses significantly affected the plant height with increasing doses up to 150%. Application of 150% gel dose registered maximum plant height (203.5 cm) as compared to control and was at par with 125% gel dose. Increase in plant height was due to more moisture retention and indirectly nutrient availability by polymer that might help to increase cell division and elongation led to increased plant height. Similar results were reported by Al-Harbi *et al*. (1996). Silberbush *et al.* (1993) concluded that hydrophilic polymer (Agrosoak) in maize and cabbage compensated for low water application, increased dry weight and increasing yield which was due to moisture stored by polymer. Plant height, leaf area and relative water content increased significantly by SAPs at 15 kg/ha (Wallace and Wallace, 1986). They also reported that rate of germination and emergence of maize increased with agricultural polymers.

Leaf area index

LAI is function of leaf area of plant divided by total ground area occupied by plant canopy. It increased progressively from 90 to 125 DAS (Table 1). At 90 and 125 DAS, stockosorb had higher LAI than Pusa gel. Differences between gel sources were non-significant. Application of 100%, 125% and 150% gel doses were on par with each other at 90 DAS and 125 DAS. Lowest LAI was recorded in control in both time intervals. El-Sayed *et al.* (1995) opined that soil amended with polymer (5-20% hydrogel) significantly increased leaf area of cotton and maize than control.

Leaf area gives a good idea of photosynthetic capacity of plant and decreased leaf area is an early response to water deficit. An increase in super absorbent polymer concentration significantly increased LAI at all stages. As water content of plant decreases, cell shrinks and turgor pressure against cell walls relaxes. This decrease in cell volume resulting from lower turgor pressure concentrates solutes in cells. SAPs increase the turgor pressure inside the cells by maintaining sufficient amount of water as per plant need and causing increase in leaf area (Yazdani *et al*., 2007).

Super absorbent polymer was more effective in increasing LAI at later stages, which subsequently resulted into higher yield. Dry matter production indicated the maintenance of dry matter production over particular period of time which is essential for supply of photosynthates to developing sink. Significantly higher dry matter production was recorded in polymer treated soil at all the stages.

El-Salmawi (2007) reported that increase in dry matter production was due to increase in carbohydrates, proteins, total amino acids and other biochemical and physiological parameters in presence of hydrogel polymer. Similarly, significant increase in dry matter production due to hydrogel polymer was reported by Silberbush *et al*. (1993) in corn and Wang *et al*. (2007) in canola. Hydrophilic polymer improves growth by increasing water retention capacity of soil and regulating plant water supplies. The increased water availability with hydrogels improved seedling growth (Woodhouse and Johnson, 1991). Similar results were reported by Al-Harbi *et al*. (1999) in cucumber and Akhter *et al*. (2004) in barley and wheat.

Table 1: Effect of different treatments on growth and yield attributes of winter maize (Pooled mean over two years)

Treatment	Plant height (cm)	Leaf Area Index		Length of cob (cm)	Number of grains/cob	1000-grain weight (g)
		90 DAS	125 DAS			
Sources of hydrogel						
G_1- Stokosorb	196.5	4.5	5.6	16.9	367.9	309.7
G_2- Pusa gel	197.8	4.4	5.3	15.3	328.9	304.5
SEm±	3.8	0.07	0.2	0.1	1.0	2.7
CD (P=0.05)	NS	NS	NS	0.6	6.0	NS
Doses of application						
D_1- Control	191.9	4.2	5.0	15.1	306.6	299.0
D_2- 50% hydrogel dose	194.3	4.3	5.1	15.6	315.9	302.0
D_3- 75% hydrogel dose	196.3	4.4	5.4	15.9	350.2	307.5
D_4- 100% hydrogel dose	197.3	4.5	5.6	16.3	362.3	309.3
D_5- 125% hydrogel dose	199.9	4.7	5.7	16.8	373.1	311.1
D_6- 150% hydrogel dose	203.5	4.7	5.9	16.9	382.1	313.5
SEm±	1.4	0.06	0.1	0.2	4.5	1.3
CD (P=0.05)	4.2	0.2	0.3	0.4	13.1	3.9

Effect of hydrogel on yield attributing characters
All the yield attributing characters of maize were significantly influenced by sources of hydrogel except 1000-grain weight. However, they were significantly differed by doses of hydrogel. Stockosorb was found superior over Pusa gel.

Length of cob
Length of cob was significantly highest under 150% gel dose being at par with 125% gel dose and was significantly higher over rest of the hydrogel doses. Stockosorb was superior over pusa gel though the effect of sources on cob length was significant.

Number of grains/cob
Number of grains/cob was significantly influenced by sources of hydrogel. However, stockosorb was found superior over pusa gel. Maximum number of grains/cob was observed under 150% gel dose which was at par with 125% gel dose and was significantly higher over rest of the hydrogel doses.

1000-grain weight
1000-grain weight was not significantly influenced by hydrogel sources. Stockosorb was superior over pusa gel. Test weight was significantly maximum under 150% gel dose being at par with 125% dose and was superior over rest of the gel doses.

An improvement in yield attributes may be due to increase in growth parameters like plant height which are influenced by super absorbent polymer in soil. An increase in growth and yield related attributes could be because of sufficient availability of water and indirectly nutrients supplied by super absorbent polymer to the plant under water stress condition, which in turn lead to better translocation of water, nutrients and photo-assimilates and finally better crop growth i.e. leaf area index.. Similar results have been reported by Sivapalan (2006) and El-Hady *et al*. (2006).

Effect of hydrogel on yield of winter maize
Yield is net result of various interactions *viz*., soil characters, weather parameters, leaf area and metabolic and biochemical interactions taking place during crop growth.

Grain yield
Since grain yield is function of cob length, test weight and number of grains/cob. Grain yield was significantly superior in stockosorb than Pusa gel. Application of 150% hydrogel dose recorded highest grain yield which was at par with 125% gel dose and was significantly higher over rest of the gel doses (Table 2). Hydrogel enhanced the growth and yield of maize in salinity condition (El-Sayed *et al.*, 1995). Highest grain yield (81.7 q/ha) was recorded under 150% hydrogel dose which was 2.1% higher than that of 125% gel dose. However, application of 100% and 125% hydrogel dose differed significantly among each other. Recommended dose of hydrogel recorded 3.3%, 10.6% and 29.2% higher yield over 75%, 50% gel dose and control. The higher grain yield in these treatments might be attributed to improved yield components.

Stover yield
Stover yield did not differ significantly due to sources of hydrogel (Table 2). It was noted superior in stockosorb than pusa gel. It was found significantly highest under 150% gel dose which was superior over rest of the gel doses except 100% and 125% dose.

Stone yield
Stone yield differed non-significantly due to hydrogel sources (Table 2). It was superior in stockosorb than pusa gel. It was maximum in 150% gel dose being at par with 125% dose and was significantly higher over rest of the gel doses. Genetic composition of crop is primary determinant of its yield potential, morphological, physiological and biochemical parameters decided the yield under water stress. It depends upon the mobilization of carbohydrates, uptake of water/nutrients from soil (Schonfeld *et al*., 1988).

In arid and semi-arid regions of northern China, grain yield of summer maize was increased slightly following super absorbent polymers application at 5 and 10 kg/ha under drought, but significantly at 15 kg/ha by 37.5%.

Table 2: Effect of different treatments on grain, stover and stone yield of winter maize (Pooled mean over two years)

Treatment	Grain yield (q/ha)	Stover yield (q/ha)	Stone yield (q/ha)
Sources of hydrogel			
G_1- Stokosorb	74.8	131.9	16.9
G_2- Pusa gel	73.3	131.2	16.7
SEm±	0.2	0.5	0.1
CD (P=0.05)	1.0	NS	NS
Doses of application			
D_1- Control	60.1	121.9	15.2
D_2- 50% hydrogel dose	70.1	131.8	16.9
D_3- 75% hydrogel dose	75.0	132.7	17.0
D_4- 100% hydrogel dose	77.5	133.1	17.1
D_5- 125% hydrogel dose	79.7	134.3	17.2
D_6- 150% hydrogel dose	81.7	135.6	17.4
SEm±	0.7	1.0	0.1
CD (P=0.05)	2.0	2.8	0.2

Effect of hydrogel on root parameters of winter maize

Root studies was done to know about the effect of sources and doses of hydrogel on root proliferation for enhanced nutrient absorption through solubilization of nutrient ions with ample amount of water and in turn led to enhanced yield.

Number of rootlets

Sources of hydrogel significantly influenced the number of rootlets and stockosorb recorded more rootlets than pusa gel. Maximum rootlets were recorded from 150% hydrogel dose which was significantly superior over rest of the gel doses. Water availability to the plant is significantly increased by hydrogel application resulting in an optimum water supply for quicker and better root growth.

Root dry weight

Variation in root dry weight owing to different gel sources was non-significant, however, they were significantly influenced by gel doses (Table 3). Stockosorb showed superiority over Pusa gel for root dry weight. Recommended dose of gel exhibited parity to 125% gel dose in regard to root dry weight. 150% hydrogel dose registered highest root dry weight which was superior over rest of the gel doses except 125% dose.

With increase in concentration of hydrophilic polymer increased the root dry weight of maize due to proper maintenance of water for longer duration. Silberbush *et al*. (1993) reported influence of hydrophilic polymer on root characteristics in tomato.

Economics

Net return

Net return of maize varied significantly due to hydrogel sources (Table 3). Stockosorb exhibited superiority over Pusa gel. Application of 75% hydrogel dose recorded highest net return (Rs. 59921/ha) which was significantly superior over rest of the gel doses except 50% and 100% dose. Further, 150% hydrogel dose exhibited the lowest net return indicating inferior to rest of the treatments except control and 125% dose. Recommended hydrogel dose recorded Rs. 3,332/ha higher net return as compared to control though cost of cultivation is about Rs. 16000/ha more than control that might be attributed due to higher yield and lower cost of cultivation. Control exhibited the lower net return that might be due to lower crop yield.

Benefit: cost ratio

B: C ratio was maximum under stockosorb source (Table 3). Control exhibited maximum B:C ratio (1.96) which was significantly superior over rest of the gel doses except 50% and 75% gel dose which might be largely due to lower cost of cultivation. Application of 150% gel dose exhibited minimum B:C ratio which was significantly inferior over rest of gel doses except 125% gel dose that was due to higher cost of cultivation owing to costly super absorbent polymer inspite of attaining highest yield.

Conclusion inferred that recommended hydrogel dose at 20 kg/ha exhibited significant enhancement in grain yield of maize and economic profitability in terms of net returns over control, apart from obtaining higher yield and returns under stockosorb gel source.

Table 3: Effect of different treatments on root characteristics of winter maize and economics (Pooled mean over two years)

Treatment	Number of rootlets	Root dry weight (g)	Net return (Rs./ha)	B:C ratio
Sources of hydrogel				
G_1- Stokosorb	37.6	126.3	58395	1.92
G_2- Pusa gel	35.9	117.4	56317	1.83
SEm±	0.2	2.7	223	0.01
CD (P=0.05)	1.1	NS	1354	0.04
Doses of application				
D_1- Control	30.9	109.0	55011	1.96
D_2- 50% hydrogel dose	34.2	113.4	59271	1.95
D_3- 75% hydrogel dose	36.0	118.3	59921	1.93
D_4- 100% hydrogel dose	37.1	126.3	58343	1.86
D_5- 125% hydrogel dose	39.5	129.5	56704	1.80
D_6- 150% hydrogel dose	42.7	134.4	54885	1.75
SEm±	0.8	2.7	768	0.02
CD (P=0.05)	2.3	8.0	2266	0.06

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