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Original Article

Evaluation of Activated Charcoal Based Hydrogels Functionalized with Maleic Acid on Growth Performance of Zea Mays in Semi-arid Regions of Kenya

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Abstract - *A Zea may (DH-02) is an early maturing crop mostly grown in arid and semi-arid regions of Kenya. A progressive productivity reduction has been witnessed due to inadequate rains and is expected to worsen in the future due to climatic changes and the increasing human population. Poor water conservation management is the major problem facing agricultural productivity in arid and semi-arid regions resulting in a lack of enough food to counter the high population growth rate. Advanced technologies are required to conserve moisture, macronutrients, and proper farm practices to boost production. The application of biodegradable superabsorbent hydrogel, capable of absorbing and retaining a large amount of water and making it available for crops during dry seasons, is of prime importance. This study applied superabsorbent hydrogels derived from activated charcoal linked with ethylenediamine and functionalized with maleic acid (HCE-2). Experimental application of HCE-2 was carried out in a randomized complete block design on a farm at Mwala Machakos County in April-July 2020. The study aimed at studying the effect of hydrogel on growth and post-harvest parameters of Zea mays. The treatment comprised the main plot with five subplots applied with doses of hydrogel HCE-2 (control, 15, 30, 45, and 60 kg/ha). The study was done in triplicates; the highest mean (%) moisture content at flowering obtained was 91.8±0.30. The highest mean growth parameters were obtained at a growth period of 60 days. The mean plant height (cm) (223.80±0.30), the number of leaves (12.33±0.58), and the mean leaf surface area (cm^2) (82.33±0.15) were obtained during a growth period of 60 days. The post-harvest mean values of the number of cobs per plant (2.00±0.00), cob length (cm) (18.10±0.27), the girth of the cob (cm) (7.90±0.10), and shelling (%) (86.43±0.31) were obtained. The mean yields (kg/ha) of Grain (1780.13±3.42), Stover (3391.33±2.81), Cob (962.73±1.27), Biological (4928.73±0.42), and Harvest index (66.53±0.31%). The findings showed that applying HCE-2 in maize plants improved the growth parameters, increasing the yields of maize planted in semi-arid regions of Mwala Machakos County, Kenya. The study shows that superabsorbent hydrogels have potential applications in agriculture.*

Keywords - *Activated charcoal, Functionalized, Hydrogels, Maize productions, Semi-arid.*

1. Introduction

Maize (*Zea mays* L.) is a major cereal crop used as a staple food in developing countries and a source of income. Maize farming is practiced in most parts of the world, and about 80% of livestock and poultry feeds are maize[1]. It is used as a raw material in many industries such as brewing, manufacturing soft drinks, and oil and protein extraction due to its high carbohydrates and other valuable micronutrients[2,3]. About 90 percent of the Kenyan population uses maize as a source of carbohydrates in the form of githeri, ugali, or popcorns[4,5]. About 70% of Kenyans on a large and small scale depend on Maize farming as a source of income, while the production cannot sustain the fast-growing population. In addition, large parts of Kenya are arid and semi-arid with inadequate and unreliable rainfall hence poor crop production. Poor methods of farming, the outbreak of diseases, and pests have affected maize production and are projected to worsen as the rainfall patterns changes due to global warming[6]. Superabsorbent hydrogels are polymeric materials with three-dimensional networks capable of absorbing a large amount of water due to their hydrophilic nature in their structure, and their application in agriculture is of prime importance[7]. Superabsorbent hydrogel HCE-2 is a biodegradable polymer capable of absorbing water to 1090% of its original weight[8]. Water is essential for crop growth as it facilitates photosynthesis, respiration, absorption, translocation, and utilization of mineral nutrients and cell division [9]. The hydrogel can absorb, retain water, and avail 90% of stored water for crop absorption during dry sessions, ensuring a constant supply of water leading to high yields[10,11]. This study investigated the effect of the dosage of superabsorbent hydrogel (HCE-2) on various growth parameters of Zea mays (DH-02) type grown in the semi-arid region of Mwala Machakos County, Kenya.

2. Materials and methods

2.1. Land preparation and cultural Practices

The Mwala Machakos County Kenya agricultural field was cultivated using jembe and then demarcated with lines and pegs into coded plots before sowing the maize seeds. Maize hybrid seeds DH 02 was planted in 16 plots. The superabsorbent hydrogel (HCE-2) adapted from[8] was applied in a split-plot arrangement of size 4.2 x 3.6 m using a randomized complete block design in replicates. The effects of moisture content percentage in superabsorbent hydrogel doses were investigated in plots 1, 2, 3, and 4 that were treated with hydrogel doses of (15, 30, 45, and 60 kg/ha) respectively. The other agricultural practices and fertilization were maintained during the study.

2.2. Percentage moisture in the plant

During the study period, a gravimetric technique was employed to determine the moisture content in maize crops at each flowering stage plot. Three randomly selected crops were uprooted in each plot, and their mean weight was determined when fresh using an electronic balance (CZ 200). The crops were air-dried at 298 K until they attained constant weight. The percentage moisture content in the plant was calculated by using equation 1

$$\text{moisture content } \% = \frac{(W_f - W_d)}{(W_d)} \times 100 \ldots\ldots\ldots 1$$

Where (W_f) was the weight obtained as fresh weight and (W_d) was the dry weight

2.3. Plant growth height

The growth height of randomly selected maize crops in each plot was measured using a meter rule. Measurement was taken from ground level to the growing tip of each crop at 15, 30, 45, and 60 days of the growth period. Each plot's average means growth height was determined and expressed in centimeters.

2.4. Quantity of leaves per Crop

The number of leaves from randomly selected maize crops from each plot was taken at 15, 30, 45, and 60 days of the growth and flowering stages. The mean values for each growth stage per plot were recorded.

2.5. Leaf surface index (LSI)

Leaf surface index is the ratio of leaves surface area per crop to the size of the land occupied by the maize crop. To determine LSI, the maize crops from the bordering rows of each plot were taken for study at 15, 30, 45, and 60 days of the growth period. The leaves of the maize crop were separated; each leaf's surface area was determined using a planimeter, and a sum of the surface area of leaves per plant was obtained. Determinations of LSI were done using equation[2].

$$LSI = \frac{\text{Leaf area per plant } (cm^{-2})}{\text{The land area occupied by the plant } (cm^{-2})} \ldots\ldots\ldots 2$$

2.6. Post-harvest studies

2.6.1 the number of cobs per plant

The number of cobs per plant crop was determined by randomly counting the number of cobs from a selection of three maize plants per plot obtained randomly at the harvesting stage. The mean cob per plant crop for each plot was determined and recorded.

2.6.2 Length of cob

Three randomly selected maize cobs from each plot were used to determine the mean cob length per plot. The cob length was measured using a meter scale and recorded in centimeters.

2.6.3 Girth of cob

The procedure adopted □□□□ was used to determine the mean girth of cob per plot. Three randomly selected maize cobs per plot were obtained to determine the perimeter of the cob. The perimeter of each cob was determined by getting the average circumference of the three regular intervals of the cob using thread at the top, bottom, and central portions of each cob. The measurements were transferred to a meter scale for reading in centimeters, followed by calculating the mean girth value per cob.

2.6.4 the number of grains per cob

After the physiological maturity of maize crops, three randomly selected crops were harvested per plot. The total number of grains in each cob was determined by counting, followed by calculating the mean number of grains of cob per plot.

2.6.5 Mass of grains per cob and cob without maize

After harvesting, the maize cobs per plot were dried in the sun to obtain a constant mass. Three dry maize cobs per plot were randomly selected then shelling was done by hand. Electronic balance determined the mass of dry grains and cobs without grains (CZ 200). The mean mass per cob and grains per cob was calculated and recorded in grams.

2.6.6 Shelling percentage

The shelling percentage of each plot was determined from three plants randomly sampled after harvest using the formula adopted from Undie[5].

$$\text{shelling } \% = \frac{\text{Mean seed weight per cob}}{\text{Mean cob weight}} \times 100\% \ldots\ldots 3$$

2.7. Yield of Maize plants

2.7.1 Mean Grain and cob yield per plot

After reaching biological maturity by dehusking and harvesting maize cobs per net plot, the harvested cobs were air-dried at room temperature until there was no change in weight. Shelling the cobs per plot was done by hand then cobs and pure dry maize were separated. Mass of pure maize grain and cobs per plot determined using electronic balance followed by mean grain and cob yield per plot then computed in Kg per hectare.

2.7.2 Mean stover yield per plot

After harvesting maize cobs, the stover per plot was harvested using a sickle, then air-dried in the sun until they turned brown. Completely dry stover was put in bundles per plot, and their mass was obtained using an electronic balance in kilograms per plot. Mean stover yield obtained then expressed in Kg per hectare.

2.7.3 Mean biological yield per plot

After obtaining the mean dry stover and cob yield per plot as described in sections 2.7.1 and 2.7.2, to obtain a biological yield, the sum mass of dry stover and cob yield per net plot was determined and expressed in kilograms per hectare.

2.7.4 Mean harvest index (%)

The mass ratio of grain yield of maize to that of biological yield. The mean grain yield and biological yield were obtained per plot as described in 2.7.1 and 2.7.3, respectively. The mean grain and biological yield ratio were computed in percentage per hectare.

3. Results and Discussions

3.1. Effect of hydrogel dosage on percentage moisture content at flowering stage

The moisture content is an essential morphological parameter for grain setting and maturing, especially during the flowering stage. An effect of superabsorbent hydrogel HCE-2 dosage on percentage moisture content is presented in figure 1.

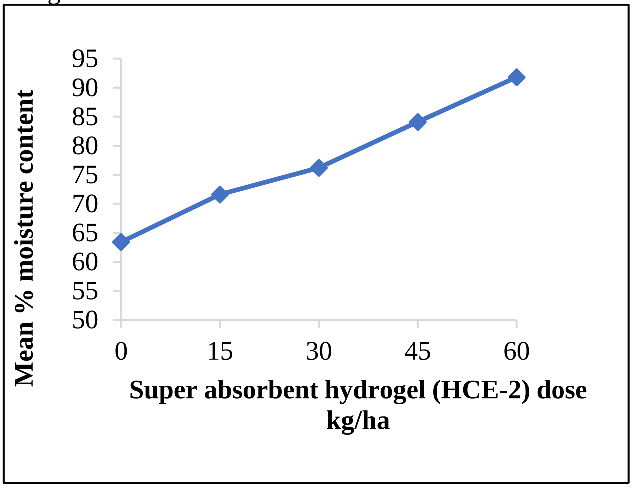

Fig. 1 Effect of superabsorbent hydrogel (HCE-2) doses on mean percentage moisture content at the flowering stage on maize crop

The mean percentage moisture content increased from 71.60±0.10 to 91.80±0.30 when the dose of HCE-2 was increased from 15 to 60 kg/ha. The mean moisture content at all studied doses differed significantly from the control experiments (Figure 1). The flowering stage of DH-02 maize occurred between the 35th to the 50th day after planting. The flowering stage, in most cases in the semi-arid regions, is characterized by a dry period. Lack of enough moisture during this vital crop growth period affects yield negatively, while enough moisture content supply is the key to grain filling and health maturity[14]. The application of superabsorbent hydrogel HCE-2 in the soil showed increased moisture content during the flowering stage as the doses were increased. This could be attributed to the addition of superabsorbent hydrogel in the soil, which absorbs moisture during rainy seasons, stores it, and then releases it to the plants when the root zone dries up, especially during the flowering and grain filling stage[5].

3.2. Effect of hydrogel dose on crop height

The height of the maize crop is one of the key morphological growth parameters. It affects the size of the cob and the number of grains per cob[16]. The mean height **of** HCE-2 hydrogel is presented in (figure 2).

(Figure 2) shows that as the dose of the HCE-2 hydrogel applied was increased, there was a corresponding increase in the mean heights of the crop as growth days increased from 15 to 60 days. The mean height (cm) increased from 5.00 ± 0.10 to 203.53 ±0.25, 7.10±0.20 to 208.57±0.25, 8.27±0.21 to 220.30±0.20, and 8.63±0.15 to 223.30±0.20 when maize plots were treated with 15, 30, 45, and 60 kg/ha of HCE-2 hydrogel respectively. Mean plant heights obtained at different hydrogel dosage treatments were higher than mean plant heights obtained using the control for the same growth period. This indicates that the application of the hydrogel positively impacted the growth of maize in this study. The results revealed that successive increases in superabsorbent applied significantly increased the mean plant height. It may be attributed to an increased rate of cell division, cell expansion, and cell elongation due to a constant supply of enough water to the root zone area of the crop[17]. The study showed that HCE-2 superabsorbent hydrogel has the potential application to boost agriculture in arid and semi-arid regions.

3.3. Effect of the growth period on the number of leaves in the maize crop at different doses of HCE-2

The number of leaves in the maize crop plays a major role in light interception, facilitating photosynthesis[17]. The effect of the dose of HCE-2 hydrogel applied to the mean number of leaves per maize plant at different growth periods is presented in (Figure 3)

(Figure 3) shows that the mean number of leaves increased from 4.67±0.58 to 12.00±1.00, 4.67±0.58 to 12.67±0.58, 5.33±0.58 to 12.00±1.00 and 5.67±0.58 to 12.33±0.58 when maize plots were treated with 15, 30, 45, and 60 kg/ha of HCE-2 hydrogel respectively. There was a rapid increase in the mean number of leaves at a growth period of 15 and 30 days, followed by a slight decrease between 45 and 60 days. A progressive increase in the number of leaves is proof of an adequate supply of moisture in the soil around plant roots throughout growth periods by applied hydrogel in the soil[18].

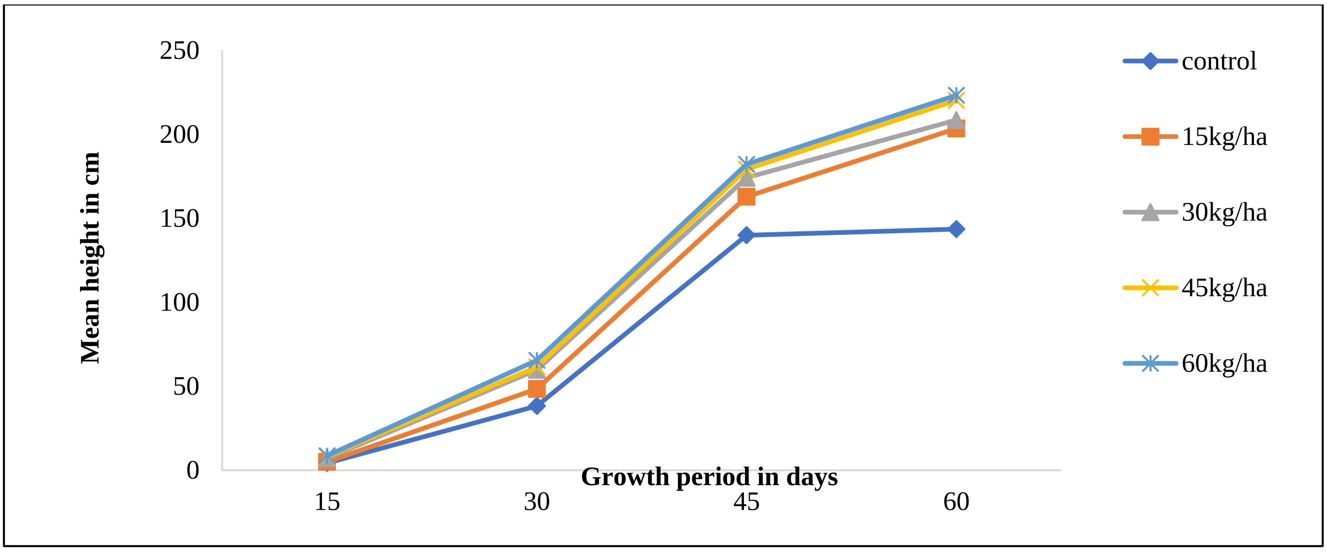

Fig. 2 Effect of growth period on plant height as the dose of HCE-2 hydrogel was varied from zero (control), 15, 30, 45, and 60kg/ha

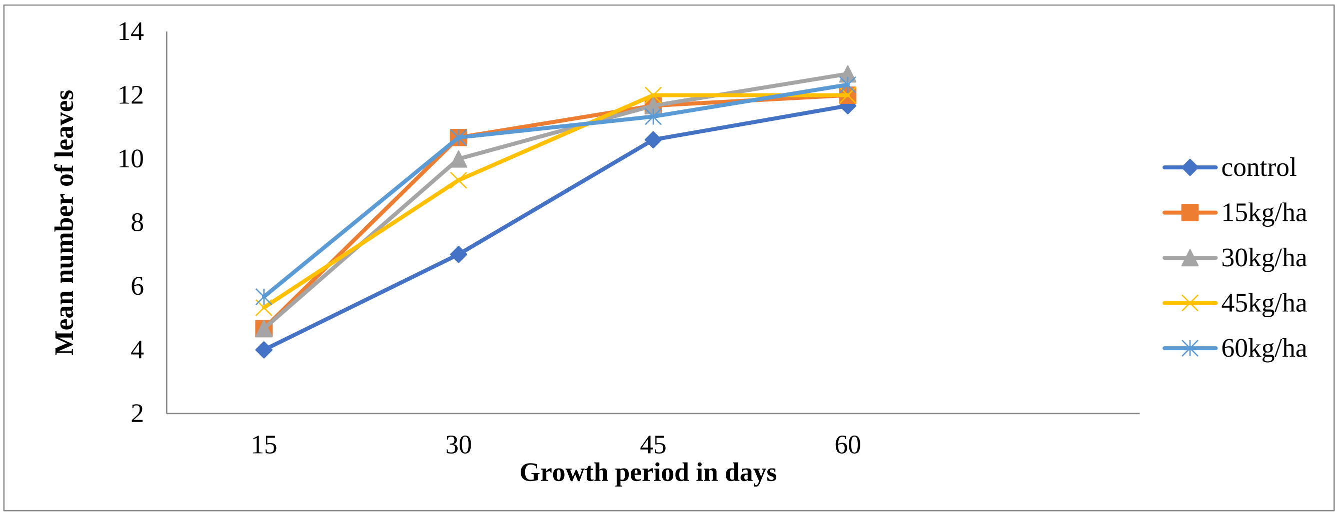

Fig. 3 Effect of the growth period on the mean number of leaves as the dose of HCE-2 hydrogel varied from zero (control), 15, 30, 45, and 60kg/ha

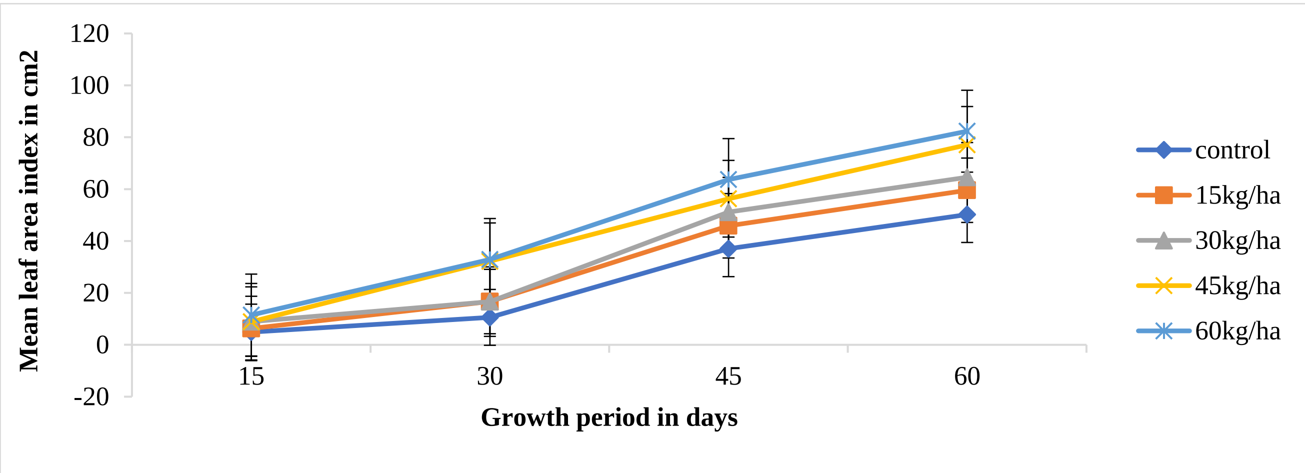

Fig. 4 Effect of growth period on mean leaf area index in cm^2 as a dosage of HCE-2 hydrogel varied from zero (control), 15, 30, 45, and 60kg/ha

3.4. Effect of dose of hydrogel HCE-2 applied on plant leaf surface index (LSI) in cm^2

The leaf surface index gives vital information about the photosynthesis potential of the plant. The decrease in leaf area index indicates a lack of moisture in plants[19]. The effect of various doses of HCE-2 hydrogel applied on plant leaf area index is shown in figure 4

(Figure 4) shows that the mean LSI increased from 6.30±0.20 to 59.57±0.32, 8.93±0.15 to 64.57±0.25, 8.87±0.38 to 77.07±0.25 and 8.87±0.38 to 82.33±0.15 as the growth period increased from 15 to 60 days when plots were treated with 15, 30, 45, and 60 kg/ha of HCE-2 hydrogel respectively. The results indicated that the mean LSI obtained at different growth periods for each dose of hydrogel applied increased progressively compared to the control experiment for the same growth period. It shows that the application of hydrogel positively impacted the LSI, suggesting an increase in the yield. The increase of LSI as the growth period increased for different doses of the hydrogel may be attributed to the increased leaf relative water content as a result of sufficient availability of soil moisture due to the application of hydrogel[20].

3.5. Effects of superabsorbent hydrogel HCE-2 dose on the number of cobs per plant, length of cob, and the girth of cob

The crop yield mainly depends on the micro and macro nutrients absorbed by the crop roots from the soil. The moisture availability influences the absorption of the nutrients in the soil. The mean values of some key post-harvest parameters obtained from this study are summarized in (Table 1). These parameters are important as they determine the yield of the maize crop.

Table 1. The effect of dosage (kg/ha) of hydrogel on the mean number of cobs per plant, length of cob, and the girth of cob

Dosage (kg/ha) of HCE-2	Number of cobs per plant	Cob length (cm)	The girth of the cob (cm)
Control	1.00±0.00^{a}	10.17±0.06^{e}	4.30±0.20^{e}
15	1.33±0.58^{a}	12.30±0.20^{d}	5.77±0.15^{d}
30	1.67±0.58^{a}	16.23±0.12^{c}	6.77±0.15^{c}
45	2.00±0.00^{a}	17.13±0.15^{b}	7.53±0.15^{b}
60	2.00±0.00^{a}	18.10± 0.27^{a}	7.90±0.10^{a}

3.5.1. The effect of dose of hydrogel on number of Cob plant^{-1}

The mean number of cobs per maize plant increased gradually from 1.33±0.58 to 2.00±0.00 as the treatment dosage of hydrogel increased from 15 to 45 kg/ha (Table 1). Though there was no significant difference between the numbers of cobs obtained as the dose of hydrogel was increased, there was a notable slight increase in the number of cobs with an increase in dosage. The presence of moisture due to the application of hydrogel improved the absorption of essential nutrients during the flowering stage hence the increased number of cobs per plant[19].

3.5.2. The effect of dose of hydrogel HCE-2 on cob length (cm)

The mean cob length of maize plants increased from 12.30±0.20 to 18.10± 0.27 cm when the applied dosage of HCE-2 was increased from 15 to 60 kg/ha (Table 1). The mean cob length of plants differed significantly as the dosage of the applied hydrogel increased and compared to the mean of the control 10.17±0.06. The cob length determines the number of grains per cob and is directly influenced by the percentage of moisture content in the crop during the flowering stage[21]. Increased cob length indicates constant water supply to the root zone of plants by applied hydrogel in the soil during the growth period[15].

3.5.3. The effect of dose of hydrogel on the circumference of the cob (cm)

The mean circumference of the cob increased from 5.77±0.15 to 7.90±0.10 cm as the dose of HCE-2 hydrogel applied was increased from 15 to 60 kg/ha. The mean circumference of the plants differed significantly as the applied dosage increased and compared to the control, which was 4.30±0.20 (Table 1). The girth of the cob determines the quantity and quality of the grains in the maize crop, which is much influenced by the percentage of moisture present in the crop. The positive impact on the girth mean diameter as the dose of the hydrogel was increased may be associated with moisture in the root zone availed by hydrogel during the flowering and the grain filling stage, which occurs during the dry period[13].

3.6. The effect of superabsorbent hydrogel HCE-2 dose (kg/ha) on the number of grains per cob, the mass of grains per cob, the mass of grain cob, and shelling percentage

(Table 2) shows the effect of different doses of superabsorbent hydrogel on the mean number of grains per cob, the mass of grains per cob, grain cob, and shelling percentage.

Table 2. The effect of dosage (kg/ha) of hydrogel on the mean number of grains per cob, the mass of grains per cob, the mass of grain cob, and shelling percentage

Dosage (kg/ha) of HCE-2	Number of grains per cob	Mass of maize cob (g)	Mass of grains per cob (g)	Shelling %
Control	225.33±5.55^{e}	136.10±0.82^{e}	60.23±0.38^{e}	44.30±0.40^{e}
15	286.00±7.55^{d}	263.00±0.27^{d}	186.23±2.57^{d}	56.33±0.31^{d}
30	336.33±5.51^{c}	288.07±0.45^{c}	223.93±0.71^{c}	68.93±0.67^{c}
45	388.00±7.55^{b}	298.87±0.40^{b}	250.40±0.92^{b}	76.20±0.10^{b}
60	397.00±4.58^{a}	363.00±0.56^{a}	257.13±0.57^{a}	86.43±0.31^{a}

Table 3. The effect of dosage (kg/ha) of hydrogel on the Grain yield, Stover yield, Cob yield, Biological yield, and Harvest index (%) per plot (kg/ha)

Dosage (kg/ha) of HCE-2	Mean grain yield (kg/ha)	Mean cob yield (kg/ha)	Mean stover yield (kg/ha)	Mean biological yield (kg/ha)	Harvest index %
Control	415.17±3.82^{e}	260.90±1.81^{e}	1917.43±1.35^{e}	2989.07±1.74^{e}	53.43±0.25^{e}
15	1362.83±5.58^{d}	556.53±1.32^{d}	3191.57±4.84^{d}	4441.53±1.19^{d}	55.53±0.40^{d}
30	1478.07±7.40^{c}	689.80±1.05^{c}	3253.50±4.05^{c}	4675.50±0.95^{c}	58.533±0.51^{c}
45	1620.53±2.91^{b}	815.60±1.20^{b}	3360.07±2.97^{b}	4829.27±0.71^{b}	63.300±0.20^{b}
60	1780.13±3.42^{a}	962.73±1.27^{a}	3391.33±2.81^{a}	4928.73±0.42^{a}	66.53±0.31^{a}

3.6.1. The effect of dose of hydrogel on number of Grains cob^{-1}

The mean number of grains per cob for maize plants increased from 286.00±7.55 to 397.00±4.58 as the dosage of applied HCE-2 hydrogel increased from 15 to 60 kg/ha. The mean number of grains per cob differed significantly as the applied dosage increased and compared to the control (Table 2). Availability of moisture and micro and macronutrients are key contributing factors toward grain filling and maturity, leading to increased grain yields[13]. An increase in the dose of the hydrogel increased the availability of moisture for absorption by the crops during the dry season of plant growth.

3.6.2. The effect of dose of hydrogel on the mass of the cob (g)

The mean cob mass increased from 263.00±0.27 to 363.00±0.56 as the dose of applied hydrogel increased from 15 to 60 kg/ha. The amount of hydrogel applied affected the mean mass of cob per maize plant and differed significantly from that of the control (Table2). The mass of the cob is directly proportional to the number of maize grains in the cob. Increased cob weight was associated with water, nutrients, and photoassimilate availability in the soil, especially during the flowering stage[30]. Applying hydrogel polymer HCE-2 in the soil benefitted in absorbing moisture and availing it for root absorption during stress conditions leading to increased cob mass[30].

3.6.3. The effect of dose of hydrogel on grains mass cob^{-1} (g)

The mean grain mass per cob increased from 186.23±2.57 to 257.13±0.57 as the applied hydrogel dose varied from 15 to 60 kg/ha. However, the doses of hydrogel significantly affected the mean values of grains mass per cob, with the plots treated with 60 kg/ha giving the highest mean (Table 2). High moisture content with increased HCE-2 dose leads to a high quantity of grains[23]. Applying the hydrogel in the soil provided enough supply of water that influenced the absorption of essential nutrients to the maize crop throughout the growth period leading to an improved number of grains per cob[24].

3.6.4. The effect of the hydrogel does apply to the % shelling

The mean shelling percentage of maize plants increased from 56.33±0.31 to 86.43±0.31 as the hydrogel polymer dose applied increased from 15 to 60 kg/ha (Table 2). The mean shelling percentage differed significantly as the HCE-2 dose applied was increased. The mean shelling percentage obtained at different HCE-2 doses differed significantly from that of the control experiment. It could be attributed to the fact that HCE-2 hydrogel absorbs moisture and is released to the crop during the time of need. Moisture availability allows the plant to absorb nutrients from the soil, increasing growth rate, high yield, and shelling percentage[25].

3.7. The effect of superabsorbent hydrogel HCE-2 dose (kg/ha) on Grain yield, Stover yield, Cob yield, Biological yield, and Harvest index (%)

3.7.1. Grain yield

The mean grain yield of maize plants increased from 1362.83±5.58 to 1780.13±3.42 (kg/ha) as the hydrogel polymer dose was increased from 15 to 60 kg/ha. The mean grain yield increased fourfold and differed significantly as the HCE-2 dose applied increased and compared to the control (415.17±3.82) (Table 3). Mean grain yield is mainly a function of cob length, weight, and the number of grain rows per cob and is influenced by the amount of moisture content in the plant during the flowering stage. The positive results are due to the availability of stored moisture by hydrophilic polymer gel, then availing the moisture to the plant's root zone area when it dries up[26].

3.7.2. Stover yield

The mean stover yield of maize plants per hectare increased progressively from 3191.57±4.84 to 3391.33±2.81 kg/ha as the applied superabsorbent hydrogel dosage was increased. Consequently, as the applied dose varied from 15 to 60 kg/ha, the average stover yield differed significantly from control plots (1917.43±1.35) (Table 3). This may be attributed to the high rate of soil water retention and preservation ability increased with increasing hydrogel polymer application. The improved soil moisture results in a healthy and fast rate of maize growth, leading to increased stover yield[27].

3.7.3. Cob yield

The result in (Table 3) indicates that as the dose of applied hydrogel increases from 15 to 60 kg/ha mean cob yield per hectare increases from 556.53±1.32 to 962.73±1.27kg/ha. Mean cob yield in kg/ha of maize plants treated with 60 kg/ha of HCE-2 hydrogel performed better than other plots at 962.73±1.27kg/ha. These mean cob yields differed significantly as varied doses were applied to increase and compared to control with 260.90±1.81. It may be due to water availability provided by hydrogel application to maize plants during cropping, catalyzing increasing cob growth rate[23].

3.7.4. Biological yield

The mean biological yield of maize plants increases as applied hydrogel dosage to the soil increases. The mean biological yield in kg/ha of maize plants increased from2989.07±1.74 to 4928.73±0.42 as the dose applied varied from zero(control) to 60 kg/ha (Table 3). However, these mean values differed significantly as the hydrogel dose varies compared to control plots. Applying hydrogel to maize plants acts as miniature water storage reservoirs, and prolonging water evaporation in the soil facilitates a high rate of root growth and increased absorption of micro and macronutrients, which are essential for the healthy growth of maize crop and increasing biological yield[28].

3.7.5. Harvest index (%)

The results in (Table 3) revealed that as the dose of applied hydrogel increases from 15 to 60 kg/ha, the mean harvest index increases from 55.53±0.40 to 66.53±0.31%. The mean harvest index in (%) differed significantly as an applied dose of hydrogel varies. Although the genetic composition of the maize crop is the major factor determining harvest index, morphological, physiological, and biochemical parameters are a key to the crop's productivity in water stress conditions. Results indicate that hydrogel application facilitates a high rate of water absorption, retaining ability, and availability to crop root zone throughout the growth period. Moreover, crop production and mobilization of carbohydrates, uptake of water and nutrients from the soil lead to rapid growth parameters, increasing harvest index[29].

Conclusion

Applying HCE-2 superabsorbent hydrogel sheds light on increasing maize production to counterbalance the fast-growing population in semi-arid regions. Increasing the dosage of applied hydrogel significantly increased mean values of growth and post-harvest parameters and shelling percentage. Therefore, the synthesis and subsequent application of HCE-2 hydrogel in maize farming have the potential for sustainable farming of maize crops in the semi-arid region of Mwala Machakos county Kenya.

Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could appear to have influenced the work described in this paper.

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