EVALUATION OF THE EFFICACY OF BELSAP HYDROGELS ON GROWTH AND YIELD OF SELECTED WHEAT VARIETIES IN MARGINAL AREAS OF NAROK COUNTY

Joseph Mutinda Komu
School of Science and Technology, Department of Agriculture. Kenya Methodist University,
P.O. Box 267-60200 Meru, Kenya
Email: mutindaxx2014@gmail.com

Peter Kamau
School of Science and Technology, Department of Agriculture. Kenya Methodist University,
P.O. Box 267-60200 Meru, Kenya
Email: pakamau52@gmail.com

David Mushimiyimana
School of Science and Technology, Department of Agriculture. Kenya Methodist University,
P.O. Box 267-60200 Meru, Kenya
Email: david.mushimiyimana@kemu.ac.ke

ABSTRACT

Wheat *(Triticum aestivum L.)* is one of the most important cereal crops in the world. According to Food and Agricultural Organization, wheat accounts for 31.4% of world cereal production and 31.5% of the total quantity of cereals traded. In Kenya, it is the second most important cereal crop after maize. To increase domestic wheat production, there is need to introduce efficient technologies as well as price and market incentives. The objective of the study was to evaluate the efficacy of Belsap hydrogels on growth and yield of selected wheat varieties in marginal areas of Narok County. Three wheat varieties (Eagle 10, Kingbird, Durra 1) and four treatments (Belsap+DAP, Belsap, DAP and Control) were applied as a replicated trial in a randomized complete block design. From the results, there were statistically significant differences between treatment means ($p<0.05$) for stand count, plot vigour, plant height, grain weight, number of tillers per plant, days to 50% physiological maturity, total biomass, yield and harvest index. Among the varieties, there were statistically significant differences ($p<0.05$) for 1000 grain weight, days to 50% physiological maturity, grain yield and harvest index. There were no significant differences for variety means for stand count, plant height, vigour, and number of tillers. Experimental plots under Belsap+DAP treatment recorded the highest performance followed by DAP, Belsap and Control. Eagle 10 variety had the best performance followed by Kingbird and Durra 1.

Keywords: Harvest Index, Super Absorbent Polymer, Wheat Varieties, Marginal Areas

1.1 BACKGROUND OF THE STUDY

Wheat crop in Kenya contributes significantly to food security, employment creation and poverty reduction in rural and urban areas. It serves as an important source of human food and forage for livestock. The national demand for wheat and its products is growing at 7% per annum and is fueled by increasing population, urbanization and change in food utilization patterns (Kamwaga et al., 2016). Though there is an increase in annual production, only 50% of domestic requirements are being met. To plug the deficit, the country imports wheat from major producing nations.

The area under wheat production in Kenya is estimated at about 100,000 hectares to 120,000 hectares while the potential is approximated at 285,000 hectares. The average yields range from less than one ton per hectare to 2.3 tons per hectare (Kamwaga et al., 2016). Low wheat yields are realized in dry land conditions where input use is very low and moisture is a limiting factor (Muasya & Mwakha, 1996). The total amount of rainfall per year in the marginal areas has significantly decreased with a negative impact on crop production. Moreover, the traditional ability to make accurate weather prediction has become much less accurate as weather patterns become variable and the environmental conditions highly unpredictable (KMS, 2015).

Scarcity of arable land and competition from other enterprises has encouraged wheat production to expand into the marginal areas (Hassan et al., 1993). In marginal areas of Narok County, wheat productivity is low due to factors such as inadequate use of certified inputs, unsuitable varieties, recurrent droughts and inadequate technologies to support production (MoALF, 2015). The crop planted in these areas experience moisture stress at critical stages of production thus it is necessary to promote technologies which can conserve moisture before and after crop establishment (Kamwaga et al., 2016). The results of the study will assist the farmers to adopt moisture conservation technologies and suitable varieties to enhance wheat production and productivity in marginal areas.

2.1 LITERATURE REVIEW

Wheat (*Triticum aestivum L.*) is one of the most important and strategic cereal crop in the world. It serves as an important staple food for about 36% of the world population in all countries (FAO, 2016). Linnaeus in 1753 first classified wheat in the grass family *Gramineae.* Although wheat is mostly grown for human food, about 10 percent is used for seed and industrial purposes. The wheat grain contains all essential nutrients; the kernel contains about 12 percent water, including carbohydrates, proteins, essential amino acids (except lysine, tryptophan and methionine), fats, minerals, vitamins and crude fibers (Kamwaga et al., 2016).

Hydrogels are hydrophilic polymer chains that highly absorb water molecules (Abedi-Koupai, Sohrab & Swarbick, 2008). Addition of hydrogels improves soil water holding capacity, decrease the rate of evapotranspiration and enhance the capacity of plants to mitigate the effects of water unavailability. In areas with a strong water deficit, mixing hydrogels with a peat-based growing medium to form root plugs is a suitable technique to enhance water availability for plants. The technology reduces water stress for seedlings after transplanting during their first months in the field and contributes to improve forest restoration methods in dryland ecosystems (Chirino, Vilagrosa & Vallejo, 2011). According to Bouranis, Theodoropoulus and Drossopoulus (1995), hydrogels absorb, expand and store water up to 400 times their own weight and consequently reduce water stress for crops.

Belsap can be used in horticultural crops, cereals, fruit trees, ornamentals, flowers, forestry, coffee, tobacco, tea, cotton and bananas. Documented results have reported crop yield increase of 22% to 45%. The application rates for field crops such as maize and wheat is 8 to 10 kilograms per hectare. Belsap can be applied in broadcast or row applications. In row application, the crystals are placed in the seed slot along with the seed. In broadcast applications, the crystals are spread evenly on the soil surface and worked down to a depth of 5 to 20 centimeters depending on the rooting system of the crop.

Belsap crystals may be applied at the same time with seeds, fertilizers and other additives without negative effects. Hydrated crystals can be degraded by ultra violet light if left on the surface of the soil hence the product should be kept buried in the soil or mulch. Belsap is nontoxic to plants, birds, fish mammals and soil organisms. According to Landis and Haase (2012), hydrogels improve soil moisture content and provide water to plants during dry seasons. This was experienced in soils treated with hydrogels that gained more soil moisture as compared to controls.

Hydrogels were developed to improve the physical properties of soils in view of increasing their water holding capacity and increasing water use efficiency. Fine texture hydrogels are suitable as root dips while coarse grades are most effective for soil incorporation. Hydrogel dips function similarly to natural mucilages produced by healthy roots (Landis et al., 2012). They are most effective in soil media, which is granular in structure with large spaces between particles (Ertan, Ahmet, & Nilgün, 2010). Due to expansion of farming activities into marginal areas, use of hydrogels is a technology that can help plants live through dry spells and enhance the resilience of farmers to unpredictable rainfall patterns. Though new in Kenya, hydrogels have routinely been used in other countries to cut down on water wastage in agriculture.

3. MATERIALS AND METHODS

3.1 Climatology and Soils

The study was done at Tibu farm, Narok West Sub-County, Narok County. The farm lies at an altitude of 1795 meters above sea level (Grid reference S 0^o 57' 478" E 35^o 24' 168") in agro ecological zone UM 4 (Maize-Sunflower zone). The experimental site has a bimodal rainfall distribution pattern (average annual rainfall of 500 to 750 mm) with the long rains falling from April to June and short rains between October and December. The soils are predominantly black cotton soils with clay and loam and are generally deficient in copper. The soil pH ranges from moderately acidic (5.5) to near neutral (6.95).

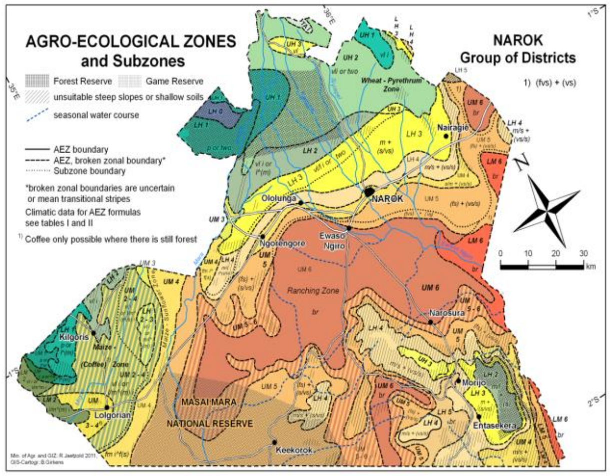


Fig 1.1: Narok County Agro Ecological Zones

3.2 Treatments and Plot Layout

The experimental plot was divided into 3 blocks and laid out in a randomized complete block design with three replications.

Variety/Treatment	Belsap+DAP (T1	Belsap(T2)	DAP(T3)	Control(T4)
Eagle 10(EA)	T1EA	T2EA	T3EA	T4EA
Kingbird(KB)	T1KB	T2KB	T3KB	T4KB
Durra 1(DU)	T1DU	T2DU	T3DU	T4DU

Table 1.1: Treatment Combinations

3.3 Land Preparation, fertilizer application and planting

Land preparation was done by ploughing twice and harrowing to a fine tilth. The main plot size was 3x2 metres separated by 30 cm intervals. Furrows were opened using a human drawn small tined tool. Fertilizer and Belsap granules were drilled by hand in the furrows and stirred to mix with soil to avoid seed scorch. Wheat was drilled in 10 rows spaced at 20 cm intervals and incorporated into the soil to a shallow depth of 2 to 3 centimeters at the onset of the rains. The crop was grown under rain fed conditions and weeds, insect pests and diseases managed as recommended. Nitrogen and Phosphorous were supplied as basal fertilizer in form of DAP

(18:46:0) at the rate of 125 kg/ha (75 g per plot) for treatments I and III. Belsap granules were applied along the rows at the rate of 8 kg/ha (6 g per plot). Nitrogen was supplied in form of foliar application at tillering stage. Weed control was done by spraying using Bucktril, a post emergence selective herbicide at the rate of 100 millimeters in 20 litres of water 30 days after germination. After 45 days, the crop was sprayed with High N (100 g in 20 litres of water) Pycop (100 millimeters in 20 litres of water) and Pyrenix (40 millimeters in 20 litres of water) insecticide to control insect pests, supply nitrogen and improve the copper content to the plant. After 60 days, the crop was sprayed using Folicur, High K and Bestox to control pests, avoid cases of rust and support grain formation.

3.4 Data Collection

Data collection was made by making observations and scoring based on a scale, measurements during crop growth and laboratory weighing after harvest. Five (5) were randomly sampled in each plot. The growth parameters monitored were stand count, plot vigour, plant height, number of tillers per plant and number of days to 50% physiological maturity. Yield parameters measured were total biomass, 1000-grain weight and total yield. Harvest index was calculated per plot using the following formula;

$$\mathbf{HI} = \frac{\textbf{Weight of grains per plot}}{\textbf{Weight of total biomass}}$$

3.5 Data Analysis

Data was summarized in excel and analyzed using SPSS Version 22. The data was presented in narrative form and visually using graphs. Analysis of Variance (ANOVA) was conducted and a probability of 5% ($p<0.05$) used to differentiate variety and treatment means according to the Least Significant Difference (LSD).

4. RESULTS AND DISCUSSIONS

4.1 Stand count

Observations on crop uniformity per plot were done between emergence and tiller production based on the Zadok's Scale. Ranking was done from 1 (very good), 2 (good), 3 (fair), 4 (poor) and 5 (very poor). Belsap+DAP and DAP treatments performed well and had the best stand count as compared to Belsap and Control. Eagle 10 variety had the best stand count for all the treatments followed by Kingbird and Durra 1.

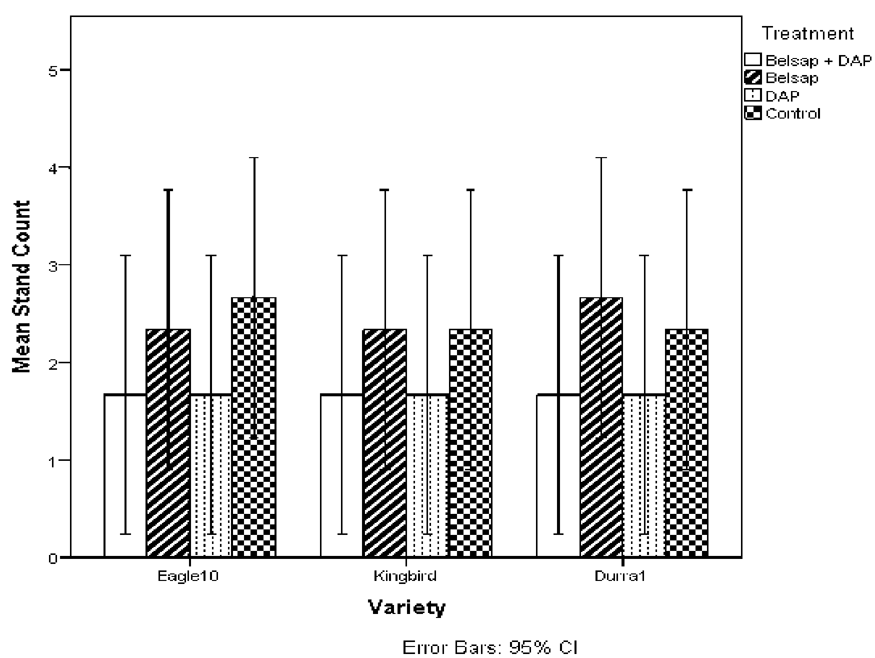


Fig 4.1: Stand Count

Analysis of variance (ANOVA) showed that there were significant differences among the treatments at ($p<0.05$). Post hoc test established that there were statistical differences in means between Belsap+DAP and Belsap, Belsap+DAP and Control and also between DAP and control.

There were no differences in means between Belsap+DAP and DAP and between Belsap and control. The results agree with Pask et al. (2012) who reported that availability of moisture and nutrients support physiological processes such as transpiration and carbon fixation by crops. These processes are the principal drivers of yield since crop ground cover is important for canopy interception of sunlight. Uniform stand count is a crucial factor for productivity in wheat since early ground cover is important for increasing crop competitiveness and reducing evaporation thus increased water use efficiency. Bereket et al. (2014) reported that availability of crop nutrients provided by basal fertilizer improves crop stand count. The nutrients support root development, photosynthesis and vegetative growth.

4.2 Plot vigour

Belsap+DAP and DAP treatments performed well and had the best plant vigour as compared to Belsap and Control. Eagle 10 performed better than the other varieties under Belsap+DAP treatment while Durra 1 performed well under Belsap treatment. The performance for all varieties was similar for DAP and control.

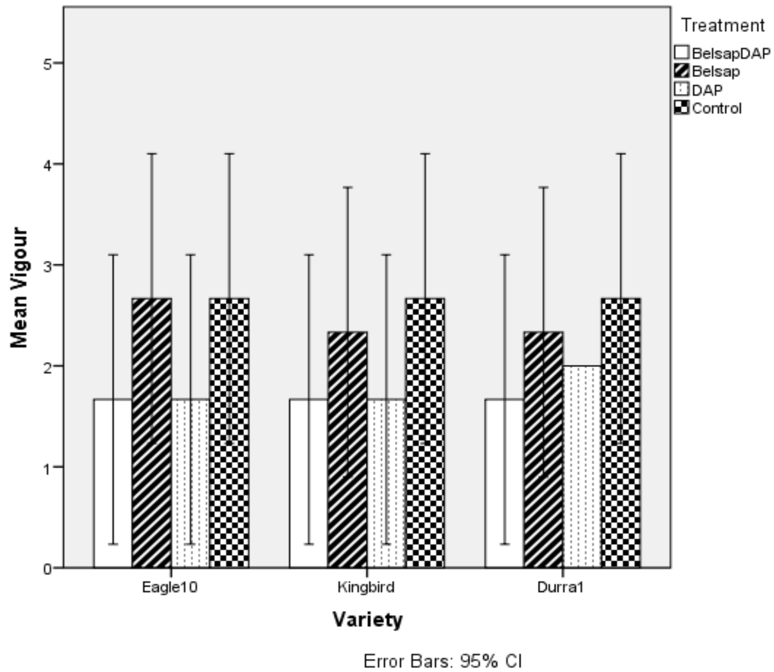
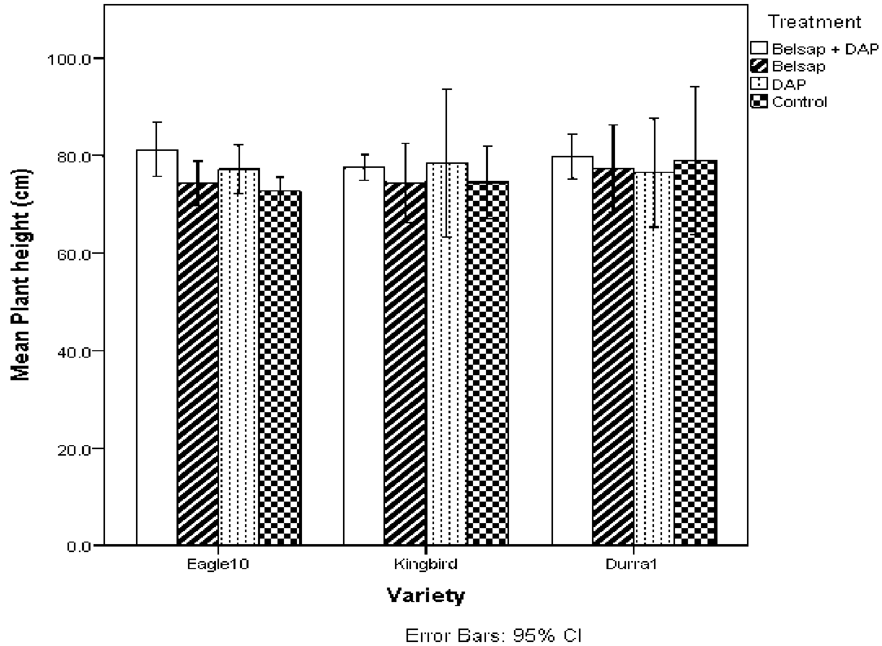


Fig 4.2: Plot vigour

From Analysis of Variance, there were significant differences at (p<0.05) among the treatments. There were no significant differences at (p<0.05) among the varieties. According to Duan et al. (2016), plant vigour is an important physiological trait determining establishment, water use efficiency and grain yield for wheat. Poor plant vigour is an indicator of stress, which may be caused by diseases, nutrient unavailability, moisture stress or temperature extremes. Plant vigour is an indicator of biomass accumulation and crop growth rate. Inadequate soil moisture and plant water status can be identified on plants through leaf rolling or tip firing. Other symptoms include early senescence, chlorosis and a poor crop stand (Pask et al., 2012).

4.3 Plant height

Five randomly selected plants were sampled per plot, measurements noted and average height calculated. Belsap+DAP and DAP treatments had the highest plant height as compared to Belsap and Control. Among the varieties, Eagle 10 recorded the highest height followed by Durra 1 and



Kingbird.

Fig 4.3: Plant height

Based on analysis of variance, there were significant differences in plant height between the treatments at ($p<0.05$). Belsap+DAP recorded a mean height of (79.9 cm), DAP (77.4 cm), Belsap (75.1 cm) and control (74.2 cm). Njuguna et al. (2004) reported that nitrogen and phosphorous application in wheat at the time of planting significantly increase plant height. According to Dagash et al. (2014) application of different rates of fertilizers influence plant height. A rate of 120 kg N/ha produced the tallest plants. This is attributed to nitrogen which being a component of protein and protoplasm stimulates cell division and elongation. Bereket et al. (2014) observed that plant height increased significantly due to Nitrogen and Phosphorus application. Plant height and structure influence the amount of light intercepted by the wheat crop during the growing season. Large canopies intercept more light which is positively linked to biomass and yield generation under optimal conditions (Pask et al., 2012).

4.4 Number of tillers per plant

Belsap+DAP treatment had the highest number of tillers per plant followed by DAP, Belsap and Control. Among the varieties, Durra 1 had the highest number of tillers for Belsap+DAP treatment while Kingbird variety had the highest number for the other treatments.

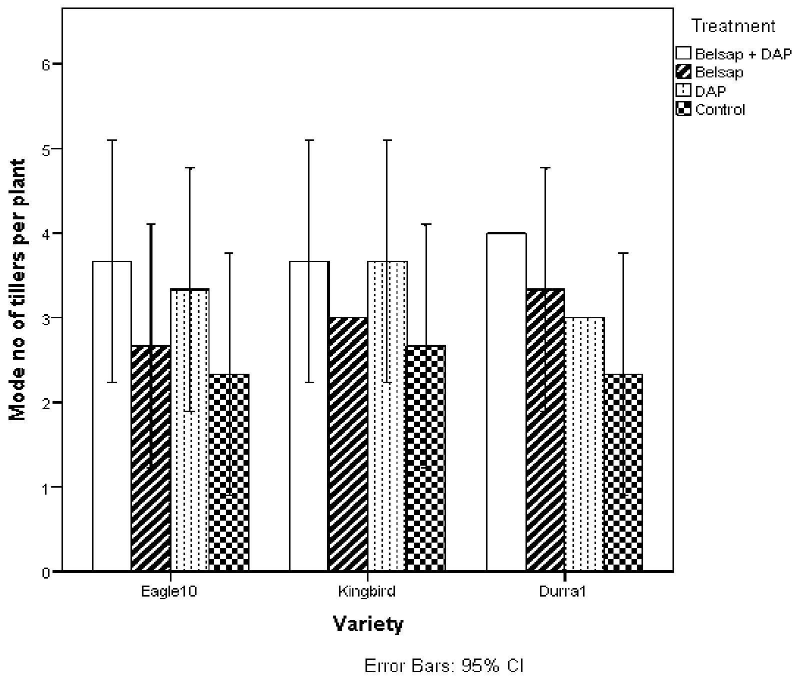


Fig 4.4: Number of tillers per plant

Availability of nutrients and moisture stimulates growth of tillers, which produce grain at harvest. Wheat plants do not tiller well under nutrient deficiency. Results obtained by Njuguna et al. (2004), reported that nitrogen and phosphorous application in wheat at the time of planting significantly increase number of tillers per square meter and grain yield. Bereket et al. (2014) observed that the number of tillers per wheat plant increased significantly due to effects of nitrogen and phosphorous application.

4.5 Number of days to 50% physiological maturity

Durra 1 variety had the lowest number of days to 50% physiological maturity followed by Kingbird and Eagle 10. Belsap+DAP had the highest number of days to 50% physiological maturity followed by DAP, Belsap and Control.

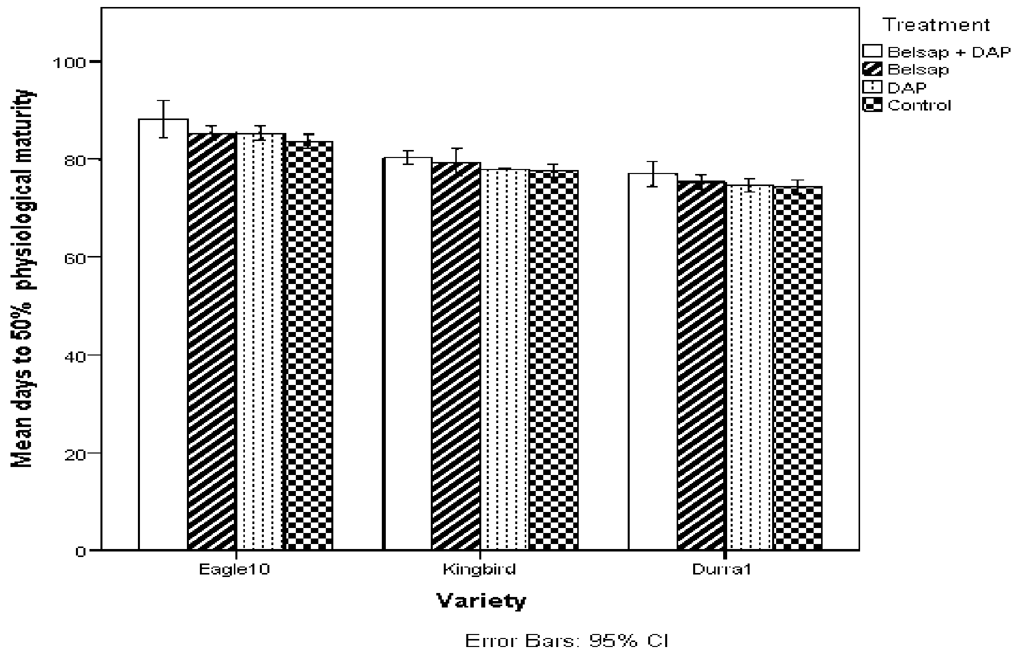


Fig 3.5: Number of days to 50% physiological maturity

There were significant differences at ($p<0.05$) among the treatments. The high number of days recorded under Belsap+DAP implies that nutrient and moisture availability has an effect on physiological maturity of wheat. According to Cheruiyot et al. (2013), hydrogels increase soil moisture availability for plants. Physiological maturity indicates the senescent phase of wheat production and is a measure of the decline in photosynthetic activity (Pask et al., 2012). According to Bekalu et al. (2016), application of less nitrogen results in delayed heading while excess application results in continuous vegetative growth. This research found out that the number of days to 50% physiological maturity was high for treatments which incorporated

Belsap and DAP as compared to control. The results are consistent with variety attributes, which indicate that Kingbird and Durra 1 are early maturing varieties while Eagle 10 is a moderately early maturing variety.

4.6 Total biomass

Eagle 10 variety had the highest biomass. Durra1 had the least biomass compared to Kingbird and Eagle10. Among the treatments, Belsap+DAP had the highest biomass followed by DAP, Belsap and Control for all the varieties.

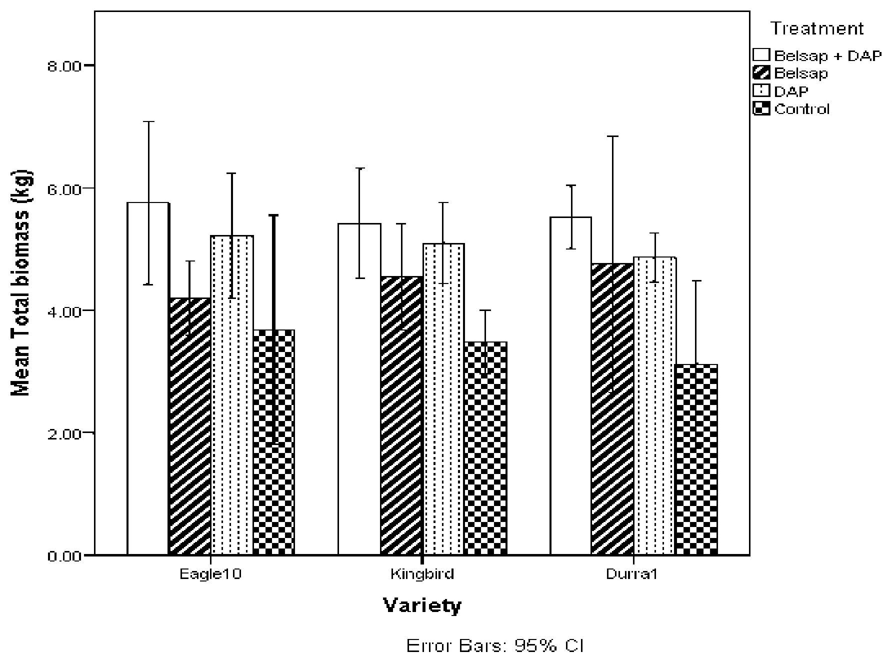


Fig 4.6: Total biomass

The analysis of variance showed that there was a significant difference in the means between the treatments at ($p<0.05$). Belsap+DAP recorded mean biomass of (5.56 kg) followed by DAP (5.053 kg), Belsap (4.498kg) and Control (3.42kg). Research by Dagash et al. (2014), observed that the influence of fertilizer and moisture on total dry matter was positive and that above ground biomass significantly increased with increased nitrogen application. Grain yield is also positively correlated with total biomass. However, high amounts of nitrogen fertilizer application results in lodging (Bereket et al., 2014). Total biomass production in wheat is affected by nutrient availability and prevailing environmental conditions. This is related to the ability of the crop to intercept sunlight and photosynthetic activity necessary for grain filling (Pask et al., 2012).

4.7 Total grain yield

Eagle 10 variety had the highest yield followed by Kingbird and Durra 1. Among the treatments, Belsap + DAP produced the highest yield followed by DAP, Belsap and Control.

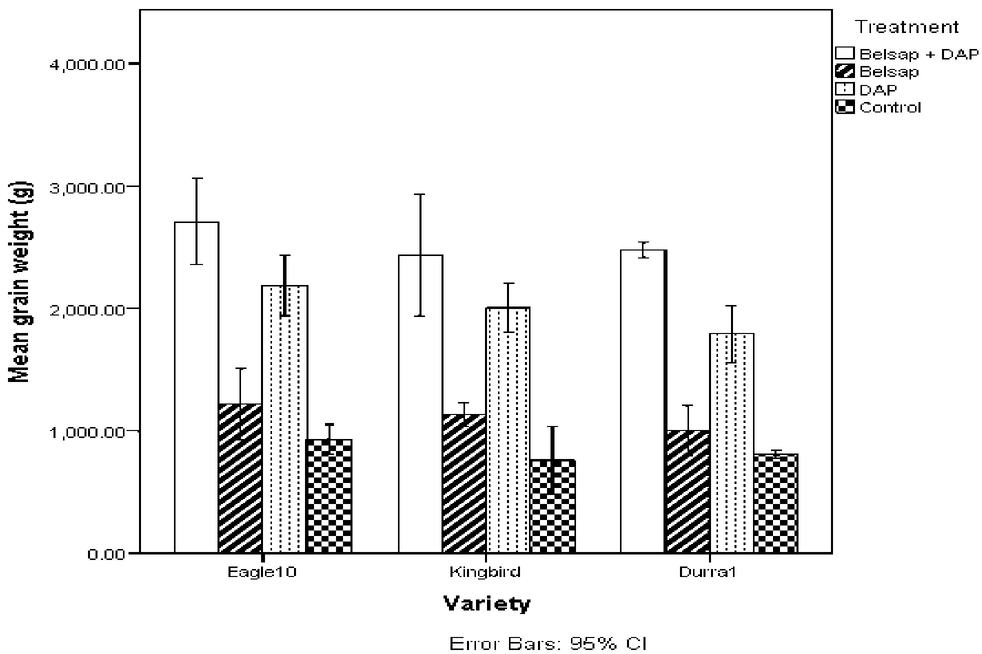


Fig 3.7: Total yield

From the analysis of variance, there was a significant difference in total yield at ($p<0.05$). Belsap+DAP performed well and had a mean weight (2541.3 g), DAP (1994.3 g), Belsap (1117.6 g) and control (832.7 g). Grain yield and other growth characteristics are positively influenced by availability of nutrients and moisture. Research by Dagash et al. (2014) reported that increasing rates of fertilizer application increase the growth of spikelets, number of grains per spikelet and enhanced yields. According to Njuguna, Mwangi, Kamundia, Koros and Ngotho (2016), application of nitrogen to wheat crop at the rate of 100 kg/ha gave the highest yield increase as compared to 75 kg/ha and 130 kg/ha.

4.8 1000 grain weight

Eagle 10 variety had the best perfomance under this parameter as compared to Kingbird and Durra 1. Among the treatments, Belsap+DAP had the best perfomance followed by DAP, Belsap and Control.

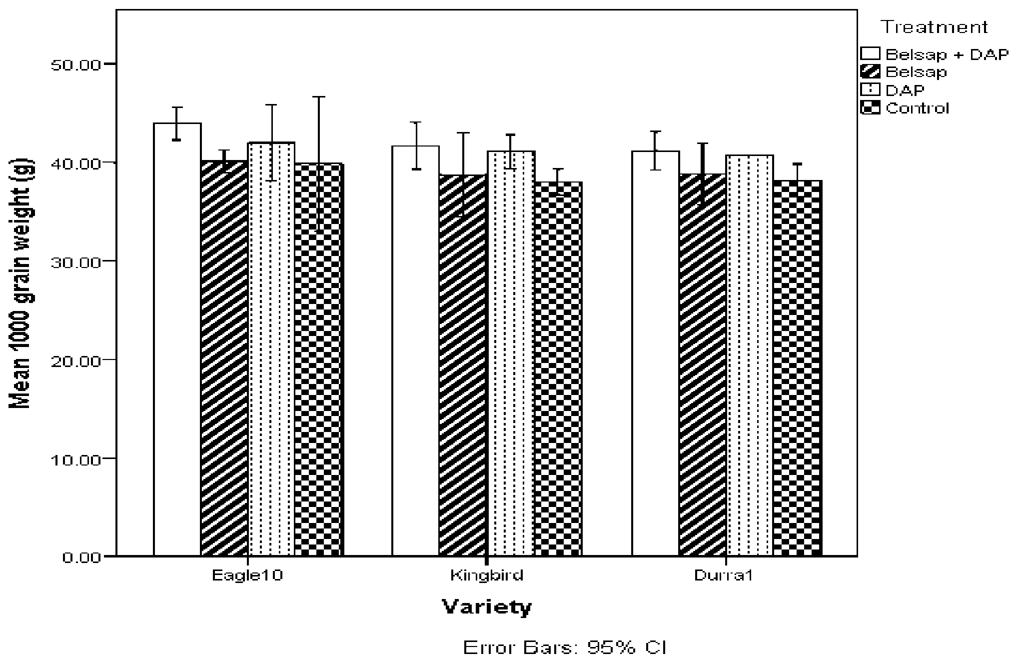


Fig 4.8: 1000 grain weight

From analysis of variance, there were significant differences ($P<0.05$) between the treatments. The results are consistent with the findings of Bekalu et al. (2016) who reported that rates and timing of fertilizer application had a significant effect on 1000 grain weight. Wheat crop planted during seasons of abundant rainfall had a higher grain weight. Bereket et al. (2014) observed that though yield is influenced by genetic factors, adequate nutrition and moisture availability are useful in expressing the genetic composition of the plant.

4.9 Harvest index

Eagle 10 variety had the highest harvest index followed by Kingbird and Durra 1. Among the treatments, Belsap+DAP produced the highest harvest index for all the varieties followed by DAP, Control and Belsap.

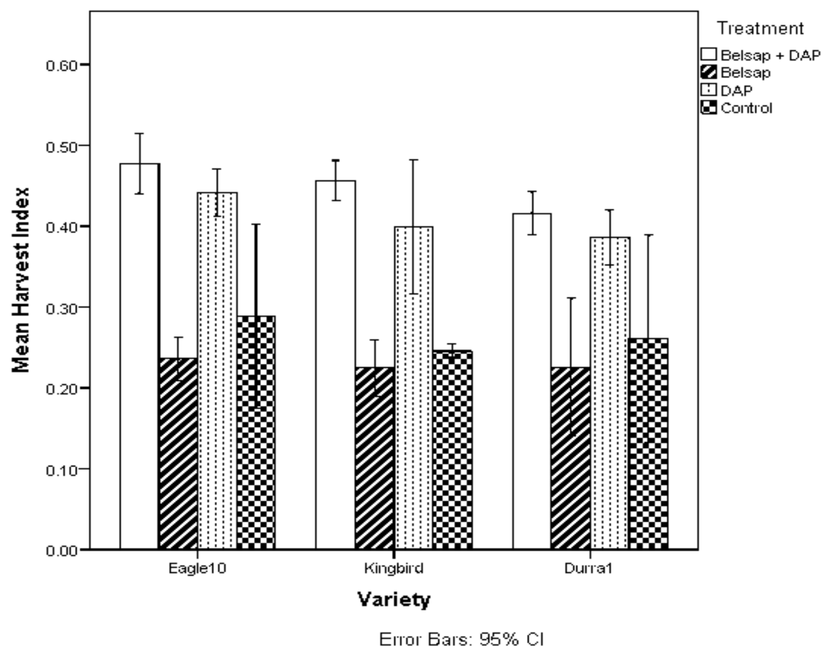


Fig 4.9: Harvest index

Post hoc tests revealed that there was significant differences at ($p<0.05$). Pask et al. (2012) reported that accumulation of water-soluble carbohydrates in wheat is influenced by genetics, environmental factors and nutrient availability. Taller varieties have large storage capacities for water-soluble carbohydrates which positively correlate with yield and harvest index. This explains the high harvest index for Eagle 10 variety as compared to Kingbird and Durra 1. This implies that nutrient availability and moisture improve the harvest index for wheat crop in the marginal areas.

5.1 SUMMARY OF FINDINGS

Availability of nitrogen and phosphorous nutrients and moisture has been determined as a yield limiting factor constraining cereal productivity. Nitrogen application significantly influences grain yield, number of kernels per head, protein content, biomass production efficiency of wheat, dry matter yield, plant height and number of tillers in wheat. Phosphorus enhances plant physiological processes such as photosynthesis, flowering, grain filling and maturation. Phosphorous fertilizer application significantly influences grain yield and number of tillers in wheat.

There were statistically significant differences between the treatment means ($P<0.05$) for stand count, plant vigour, plant height, grain weight, number of tillers per plant, days to 50% physiological maturity, total biomass, yield and harvest index. Plots under Belsap + DAP treatment recorded the best performance for all variables under consideration followed by DAP, Belsap and Control respectively. Among the varieties, there were statistically significant differences ($P<0.05$) for 1000 grain weight, days to 50% physiological maturity, grain yield and harvest index but no significant differences for variety means for stand count, plant height, vigour, and number of tillers. Eagle 10 variety had the best performance for stand count, vigour, plant height, number of tillers, grain yield and harvest index followed by Kingbird and Durra 1. Durra 1 had the lowest number of days to physiological maturity followed by Kingbird and Eagle 10.

Previous research indicates that the harvest index for wheat is 0.55. From these results, there was significant difference between the treatments and varieties. Belsap + DAP recorded the highest harvest index followed by DAP, Belsap and Control. Among the varieties, Eagle 10 recorded the highest harvest index followed by Kingbird and Durra 1. There were no significant differences in plant height among the selected varieties but significant differences were observed between different treatments. The number of days to physiological maturity was significantly different between the treatments and varieties which can be attributed to the variety characteristics and availability of nutrients and moisture.

5.2 CONCLUSION

This study showed there were statistically significant differences between the treatment means ($p<0.05$) for stand count, vigour and plant height. Belsap+DAP recorded the highest score followed by DAP, Belsap and control. From the research, it can be concluded that stand count, vigour and plant height have an influence on other variables such as tillering, grain yield and biomass production. Eagle 10 variety had the highest plant height followed by Kingbird and Durra 1. Experimental plots under Belsap+DAP recorded the best performance for growth and yield attributes. It can be concluded that use of Belsap hydrogels combined with adequate fertilizers improves the performance of wheat in the marginal areas where moisture and nutrients are limiting factors in production. Under all treatments, Eagle 10 variety performed the best in yield than Kingbird and Durra 1. The variety is therefore recommended for adoption by farmers in marginal areas of the county.

5.3 RECOMMENDATIONS

From the study, the following recommendations can be made;

It is viable to include Belsap as an input in the production process of wheat in the marginal areas of Narok County. Summary comparisons between Belsap + DAP and DAP treatments indicates that there was a significant increase in yields. Belsap + DAP treatment also recorded the highest biomass weight as compared to other treatments. Under all treatments, Eagle 10 variety performed the best in yield than Kingbird and Durra 1. The variety is therefore recommended for adoption by farmers in marginal areas of the county. Where long term average rainfall is low, the other two varieties, Kingbird and Durra 1, can be recommended for production in the marginal areas because of the fewer number of days to 50% physiological maturity.

For optimum production, farmers should adopt soil sampling and testing to determine the nutrient requirements of their crop and reduce cases of soil acidity or alkalinity which may result in fixation of some nutrients even though they are available in the soil. Further studies can be done to compare the effects of hydrogel application on a range of different soil types, effects on hydrogels on wheat grain quality and changes in soil nutrient and moisture status during the growth period of the wheat crop. Further research to compare growth and production of wheat through the application of varying quantities of fertilizer and different types of hydrogels in marginal areas is recommended.

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