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Effect of Inter-and Intra-Row Spacing on Yield and Yield Components of Maize QPM Hybrid, BHQPY545 in Southwestern Ethiopia

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ABSTRACT

The field experiments were carried out at Jimma Zone, Omonada woreda and Illu-Ababor Zone, Gehi woreda during 2013 and 2014 main cropping season. The treatments consisted of factorial combinations of four inter each of inter (55, 65, 75 and 85 cm) and intra (20, 25, 30 and 35 cm) laid down in a randomized complete block design (RCBD) with three replications using maize hybrid, BHQPY545. Across season and site results showed that highly significant differences (P<0.01) effect due to inter and intra row spacing of plant population density among Number of cob harvested, Grain yield, and Biomass yield were observed while Stem Girth has significant differences (P<0.05) due to effect of inter and non-significant on intra in 2013. Also, Plan height and logging sowed significant (P<0.01) interaction in 2013 and grain yield in 2014. The highest mean grain yield (87.78 t ha^{-1}), (80.72 t ha^{-1}) recorded from (55cm and 20cm) respectively which is the highest (90,909) plant population per hectare. While the lowest was recorded from (85x35) (33613) plants per hectare. In general grain yield showed a linear relation with inter and intra row spacing. Based on farmer's perception criteria's like cob, stalk size and technically applicability 75% of them chosen for plant density of 66,666 plants/ha (75 x 20 cm) grain yield increments by farmer's selected (75x25) and it showed 13.02 and 8.65 % with inter and intra row respectively as compared to check treatment which was lowest plant density (44,444 plants/ha). The Partial budget analysis showed treatments higher net benefit 20584 and 21525 EtB and MMR of 1588% and 181% were recorded from 75 x 25 cm inter and intra row space, respectively (Table 10). Therefore, from farmers perception and current on-farm input availability, technical applicability and economic feasibility, a plant density of (75 x 20 cm) 66,666 plants/ha taken as optimal density and recommended for the production of BHQPY545 in Omonada, Buno Bedele and other similar humid agro-ecologies of the west and southwest Ethiopia.

Keywords: *Maize hybrid, BHQPY545; Inter and intra row; Plant population density.*

INTRODUCTION

Like any other tropical countries, most cropping systems in Ethiopia are traditional and crop bases are complex, vary across agro-ecologies and diverse according to cultural food needs of resource-poor farmers. Maize is commonly planted in rows of varying spaces, less effort has been made to plant at optimum densities to maximize its productivity in different agro-ecologies of Ethiopia. Summaries of earlier results (1970s and 1980s) from different studies on maize plant population densities indicate that better yields were obtained at planting density in a range of 4-7 plants/m2 Tenaw, W. et al., (1992). Later studies confirmed that at 5-7 plants/m2 medium to late maize maturity groups gave maximum yields in humid regions, while early maturity groups produced maximum yields at higher densities in both humid and moisture stress areas Tenaw, W. et al., (2002). It is being observed that lately innovated medium and early maize varieties in humid lowlands and low moisture stress area found to be varied in structure and leaf arrangements from known normal maize varieties. These variations in morphology may lead to different planting density to reach at their at maximum yield potentials.

Plant population density has a significant impact on growth and yield of crops, including maize, a popular C4 cereal crop Cox, (1996). Therefore, understanding how plants regulate their growth in response to plant population densities has problems, such as determination of optimal sowing density Cox, (1996). Increased plant populations could lead to increased yields under optimal climatic and management conditions due to the greater number of smaller cobs per unit area Bavec and Bavec, (2002).

Plant population is the prime factor for getting maximum yield which is decided by inter and intra row spacing of crops. Decreasing the distance between neighbor rows at any particular plant population has several potential advantages. First, it reduces competition among plants within rows for light, water and nutrients due to a more equidistant plant arrangement Olson and Sander, (1988). The more favorable planting pattern provided by closer rows enhances maize growth rate early in the season D. G. Bullock et al., (1988), leading to a better interception of sunlight, a higher radiation use efficiency and a greater grain yield (Westgate et al., 1997).

Secondly, the maximization of light interception from early canopy closure also reduces transmittance through the canopy McLachlan et al (1993). The smaller amount of sunlight striking the ground decreases the potential for weed interference, especially for shade-intolerant species Gunsolus, (1990). Thirdly the quicker shading of soil water being lost by evaporation D. L. Karlen and Camp, (1985). This is especially important under favorable soil surface moisture conditions because it allows maize plants to maximize photosynthesis and the proportion of water that is used growth processes rather than evaporated from the soil (J. Lauer, 1994). Furthermore, earlier crop cover provided by smaller row width is instrumental to enhance soil protection, diminishing water runoff and soil erosion Sangoi et al., (1998). The nutrient use efficiency can be improved with the use of optimum plant population Srikanth et al., (2009). Besides, MJ. Carena and Cross (2003) had suggested that higher plant population densities are encouraged for germplasm improvement to facilitate foraging of the unwanted plants.

Currently, these new maize versions are known as quality protein maize (QPM) and promised to solve higher food and feed demands of maize consumers S. K. Vasal, (2000). Most QPM varieties have some morphological differences as compared to previous normal maize varieties that may lead to responses at higher plant population density. However, according to (Duncan 1984) plant population above critical density has a negative effect on yield per plant due to the effects of interplant competition for light, water, nutrient and other potential yields limiting environmental factors. Therefore, understanding how maize plants regulate their growth in response to plant population densities and fertilizer rates had been a crucial task about maize varieties having varying morphological structures. As a result, testing of new maize QPM hybrids at higher densities in the range of three to ten plants per square meter was becoming very indispensable research area to reach at their maximum yield potentials.

Materials and Methods

Description of the Study Area

The current field experiments were conducted in at two sites of Omonada woreda, Jimma Zone and Gehi, Illu-Ababor Zones Southwestern Ethiopia at farmers' fields in main cropping seasons of 2013 and 2014. The sites were located on 7º46' N and 36º 00'E and laid at an altitude of 1753 m.a.s.l. with soil type of the area is Upland: Chromic Nitosol and Combisol. The average maximum and minimum temperature are 9ºC and 28ºC respectively and reliably receive good rains 1561 mm per annum cropping season. While Illu-Ababor Zones Gehi was located at 8°18′N 35°35′E and an altitude of 1500 – 2000 m.a.s.l. The soil type that developed from parent material nitosols and lixisol. The average maximum and minimum temperature are varied between 16ºc and 24ºc respectively and reliably receives good rains 2000 mm per annum cropping season.

Experimental Treatment and Procedures

The quality protein maize hybrid, known as BHQPY545 is an early maturing variety adapted to low-mid altitude (1000-1800 masl) areas with high protein. It was released in the year 2008 and its yield potential is 8-10 t ha-1(EIAR, 2008). It was yellow-coloured. It has been observed that lately innovated maize varieties such as quality protein maize (QPM) types vary in stature and leaf arrangements from known normal maize varieties. These variations in morphology may lead to different planting density to reach at their at maximum yield potentials. Because of this, plant population density study on QPM hybrid (BHQPY 545) was used for experiment with two objectives to maximize yield potential and to help smallholder farmers to feed their families with the high protein diet.

The treatments consisted of factorial combinations of four inter each of inter (55, 65, 75 and 85 cm) and intra (20, 25, 30 and 35 cm) spacing corresponds to population densities

33613, 39216, 47059, 58824, 38095, 44444, 53333, 66667, 43956, 51282, 61538, 76923, 51948, 60606, 72727 and 90,909 plant ha-1totally sixteen treatments laid out in a randomized complete block design (RCBD) with three replications. Blocks were separated from each other by 1.5 m wide-open space, while experimental plots within replications were separated by 1 m apart from each other. The gross size of each plot was 5.1 m length by 4.5 m width (22.95 m^2) accommodating 5 - 8 rows. The inner 3-6 rows used for data collection. Nitrogen and phosphorus fertilizers at 92 kg ha-1and 69 kg/ha (P_2O_5) current recommendation were applied, respectively per stand or hill base. To increase the nitrogen use efficiency, it was split in two equal rates and applied at planting time and knee height stages.

The experimental field was prepared following the conventional tillage practice and furrow opened by using oxen. Two maize seeds were planted per hill and thinned after establishment to maintain a single healthy plant per hill. All other agronomic practices like three times hand weeding were applied uniformly to both experimental plots as per their respective recommendations for maize in the study area.

Data Collection

The data collected were growth, yield, yield related and other agronomic data were collected.

Economic Analysis

To assess the costs and benefits associated with different treatments (inter and intra row spacing), the partial budget technique as described by CIMMYT (1988) was applied. Economic analysis was done using the prevailing market prices for inputs at planting and outputs, at the time the crop was harvested. All costs and benefits were calculated on ha-1basis of Ethiopian Birr (EtB). The inputs and/or concepts used in the partial budget analysis were the mean grain yield of each treatment in both years, the field price of QPM Hybrid, BHQPY545 maize grain (sale price grain yield minus the costs of fertilizer, planting, seed), the gross field benefit (GFB) ha-1(the product of field price of the mean yield for each treatment), the field price of Seed rate kg ha-1, fertilizer and wage rate, the total costs that varied (TCV) which included the sum of field cost of seed, fertilizer and its wage for planting and application. The net benefit (NB) was calculated as the difference between the GFB and the TCV. Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. There were optimum plant population density, timely labour availability and better management (e.g. weed control, rainfall) under the experimental conditions CIMMYT, (1988). The dominance analysis procedure as detailed in CIMMYT (1998) was used to select potentially profitable treatments from the range that was tested.

The discarded and selected treatments using this technique were referred to as dominated and undominated treatments, respectively. The undominated treatments were ranked from the lowest to the highest cost. For each pair of ranked treatments, the percent marginal rate of return (MRR) was calculated. The MRR (%) between any pair of undominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns the MRR (%) was calculated as changes in NB divided by changes in cost. Thus, the MRR of 100% was used indicating for every one EtB expended there is a return of one EtB for a given variable input.

Sensitivity analysis for different interventions was also carried out to test the recommendation made for its ability to withstand price changes. Sensitivity analysis simply implied redoing the marginal analysis with the alternative prices. Through sensitivity analysis, the maximum acceptable field price of input was calculated with the minimum rate of return as described by Shah et al. (2009).

Data Analysis

Analysis of variance (ANOVA) for all collected data was computed using R software version 3. 5.3 statistical software R Core Team (2019-03-11). Whenever the ANOVA results showed the significant differences between sources of variation, the means were separated using Fisher's least significant difference (LSD).

Results And Discussion

Analysis of variance (ANOVA) for the effects of inter and intra row spacing both seasons and location were did not show significant ($P <0.05$) interaction all parameters. Plan height, ear height, number of cobs harvested, grain yield, and biomass were significantly ($P <0.01$) influenced by both inter and intra row spacing across location and year (Table 6). Similarly, all parameters were highly significantly (P<0.01) influenced by the main effects of inter and intra row spacing except only stem girth was showed significantly (P <0.05) influenced inter row spacing in 2013 (Table 1) and grain yield and plant height at 2014 and 2013 showed significantly (P <0.01) interaction effect.

Plant Height

The plant height was significantly (P<0.01) influenced by the main effects of inter and intra row spacing and also interaction effect across both locations at 2013 (Table 6 and 4). The highest plant height 272.57 and 274.23 cm were measured from 20 and 55 cm inter and intra row respectively from the highest density (90,909 plants ha^{-1}). However, the shortest 264.25 and 261.41 cm were measured from 85 and 35 cm inter and intra row respectively from the lowest density (33,613 plants ha^{-1}). Generally it ranged from 272.57 to 264.25 cm and 274.23 to 261.41 cm with increased inter and intra row respectively (33,613 - 90,909) so, Plant height increased significantly with the increasing of plant planting density because of plants computes for light and nutrients when densely populated and it shows the same trend across location (Table 1). The result was in agreement with (Al-Rudha and Al-Youmis, 1998) that maize sown at 15cm had maximum plant height compared with their counterparts sown at wider intra-row spacing. Rafiq MA., et al, (2010) reported that plant density significantly increased the plant height in hybrid maize. These result confirmed that the findings of Sherifi RS., et al. (2009) in maize hybrid.

Ear Height at Maturity

At both locations, ear height was significantly (P<0.01) affected by the main effect of both inter and intra row only in 2013 (Table 1). The main effect of inter and intra row showed that ear height was responsive to the change in planting density. The highest (90,909 plants ha^{-1}) or (20 and 55 cm) intra and inter-row resulted in the tallest ear height (144.53 and 142.34 cm) respectively whereas; the shortest ear height (125.65 and 122.29 cm) was measured from (35 and 85 cm) intra and inter-row or 44444 plants ha^{-1}. Generally, ear height showed a linear increase with an increase in planting density increase due to high density resulted in competition for resources. The current result was in agreement with Zeleke A. et al., (2018) the main effect of planting density showed that ear height was relatively responsive to the change in planting density than N levels.

Stem Girth

The stem girth was significant differences (P<0.01) effect due to inter and intra row spacing across location, season and there were significant differences (P<0.01) effect due to inter However, neither the main effect of intra row spacing nor the interaction effect influenced ear height at 2013 (Table 6 and 1). The highest stem girth 2.69 and 2.66 cm were recorded from the highest 85 and 35 cm inter and intra row spacing respectively and the lowest 2.59 and 2.60 cm from the lowest 55 and 20 cm inter and intra row spacing respectively. The result shows that an increase with an increase in inter and intra row spacing that the wider area planted crops can exploit more nutrients and moisture for growth and development that results for stem growth also. Similarly, Enujeke E. C. (2013a) reported maize plants sown at a spacing of 35cm were superior in stem girth over those sown at narrower or smaller spacing possibly because the plants obtained more soil moisture and nutrients than narrower-spaced plants. This is similar to the findings of Barbier et al. (2000); Hamayan (2003); Dalley et al. (2006) and Azam et al. (2007) who reported that wider-spaced maize plants obtained more soil moisture and nutrients than narrower plants.

Number of Cobs Harvested

The highest number of cobs harvested 71242 and 71050 were recorded from the highest density (90909) or the narrowest spacing of 55 and 20 cm inter and intra row spacing respectively while the lowest 50880 and 55020 cobs ha^{-1} were recorded from the lowest density (33613) or widest spacing of 85 and 35 cm inter and intra row spacing respectively. It was significant differences (P<0.01) effect due to inter and intra row spacing across location and season but didn't show interaction effect (Table 6). The result shows that as inter and intra row spacing decrease there was a linear increase in many cobs harvested due to plant density increase leads to cob weight increase and directly grain yield increase Similar report by Allessi and Power (2004) revealed that maize cob weight decreased with increased plant population.

Biomass Yield

The biomass yield was significant differences (P<0.01) effect due to inter and intra row spacing across location and season (Table 1 and 2). The highest biomass yield 15.51 and 15.76 cm were recorded from the highest density of 90909 plants per hectare or the narrowest spacing of 55 and 20 cm inter and intra row spacing respectively from the highest plant population density. On the contrary, the lowest 13.52 and 13.23 t/ha from the lowest density of (33613) or 85 and 35 cm inter and intra row spacing respectively (Table 6). The result shows that an increase in biomass yield with increasing plant population density and plant height also directly contribute to biomass yield increment. These result in agreement with there was an increment of biomass yield parallel with an increase in planting density rate since there is the presence of more number of stands per unit area, improved translocation of dry matter accumulation, efficient N uptake and presence of increased competition for light Zeleke et al., (2018). Several studies have shown that biomass yield increases progressively as the number of plants increases in a given area at a certain level Hamidi A, et al., (2010). Aslam et al., (2011) reported that dry matter accumulation was much in high plant densities compared to low plant densities.

Grain Yield

Maize grain yield was significantly ($P<0.01$) affected by the effect of inter and intra row spacing of planting density across location and season and interaction effect was significantly ($P<0.01$) at 2014 across locations (Table 6 and 3). The results of ANOVA showed that the highest mean grain yield (8.78 t ha -1) and (8.07 t ha^{-1}) was achieved from 55 and 20 cm inter and intra rows respectively (Table 6). Similarly, the highest grain yield from the interaction effect across the location of 2014 (8.49 kg ha^{-1}) (Table) was obtained from the highest planting density (90909 plants ha^{-1}). These were showed yield increments by 32.60% and 13.66 % with inter and intra row respectively as compared to check treatment which was lowest plant density (33613 plants ha^{-1}) rows respectively. Brown et al. (1970) reported finding a 34% yield increase for corn grown in 51-cm row spacing. In all cases, the grain yield was significantly increased with increased planting density from (33613 plants ha^{-1}) to (90909 plants ha^{-1}). Which means that planting density determines the number of cobs harvested and that directly increase in grain yield since the recommended fertilizer rate applied per hill base. This result showed that high planting density and fertilizer were beneficial for optimum yield when all other conditions like light, soil moisture and nutrient are favorable to attain the highest grain yield in maize. These results conform to Bozorgi HR. et al. (2011) also reported that maximum maize grain yield obtained from the combination of highest planting density with the highest in N fertilizer levels. On the contrary, the lowest grain yield of (6.62 t ha^{-1}) and (7.10 t ha^{-1}) was recorded from the lowest planting density (33613 plants ha^{-1}) or 85 and 35 cm inter and intra row spacing respectively (Table 3).

Farmers' Perception of Optimal Plant Population Density

The farmer's perception was collected at green ear stage and harvest period on densities 75 x 30 (44,444), 75 x 20 (66,667), 75 x 15 (88,889) and 80 x 40 two seed per hill (62,500) by considering maize stand eight evaluation criteria's like maize growth rate, probability of lodging, number of ears/plant and yield potential sated by farmers based on interest on stalk thickness, cob size and technical feasibility to decide optimal plant density recommendation for BHQPY545 (Table 7). Because farmers of the study area practices mixed farming system that they prefer stalk thickness to feed cattle's, locally homemaking and cob size since it affected by high density. So, that even though the highest density 55x20 cm (90909) was given the highest grain yield. Finally, based on maize stand evaluation criteria that were set by farmers (Table 7) that 75% of them chosen for a plant density of 66,666 plants/ha (maize spacing of 75 x 20 cm).

Economic Viability of Inter and Intra Row Spacing

Analysis of variance (Table 6) showed that seed rates and row spacing had a significant ($P = 0.001$) effect on the grain yield of QPM Hybrid, BHQPY545 maize whereas interaction was not significant. An economic analysis of the combined results using the partial budget technique was thus appropriate (CIMMYT, 1988). The result of the partial budget analysis and the data used in the development of the partial budget are given in (Tables 8 and 9). It was performed by considering fertilizer cost, application cost, and labour as main input, mean grain yield obtained across season and location. The total costs of fertilizers (NPS = 15.90 EtB/kg and urea = 12.65 EtB/kg and sale of grain maize at Omonada open market average price (3.00 EtB/kg).

Dominance analysis (Table 9) led to the selection of treatments only 85, 75cm from inter and 35,30 and 25cm were ranked in increasing order of total costs that vary. Even though there was an increase in grain yield, lead in an increase gross field benefit and decrease in net benefit with an increase in plant population density, labor and also fertilizer rates. The treatments having MRR below 100% was considered and unacceptable to farmers; thus, 30cm intra row was eliminated (CIMMYT, 1988). This was because such a return would not offset the cost of capital (interest) and other related deal costs while still giving an attractive profit margin to serve as an incentive. Therefore, this investigation remained with changes to 85 and 75cm from inter row, 35 and 25cm intra row as promising new practices for farmers under the prevailing price structure since they gave more than 100% MRR. These results agree with (Tariku B., et al, 2018).

Market prices are ever changing and as such are the calculation of the partial budget using a set of likely future prices *i.e*., sensitivity analysis, was essential to identify treatments which may likely remain stable and sustain satisfactory returns for farmers despite price fluctuations. This study indicated that an increase in the price of the grain of Birr 1 per kg and labor 10 birrs person per day an increase (Table 10).

These price changes are realistic under the liberal market conditions prevailing in Omonada and Buno Bedele at the time of experimentation. Some of the considerations in projecting prices were decreased maize due to supply to displacement of peoples due to insecurity and also it's ever inflation in Omonada and Buno Bedele. The new prices were thus used to obtain the sensitivity analysis (Table 6) Changing from treatments 85 to 75 cm inter row and 35 to 25cm intra row gave 1588 and 181% MRR, respectively (Table 10) which were above the minimum acceptable MRR of 100% except 85 cm inter and 35cm intra row spacing which was below the minimum acceptable MRR. MRR (%).

This might suggest the use of inputs that result in maximum net benefits (Bekele, 2000). Therefore, 75 cm inter and 25 cm intra row spacing with high net benefit 20584 and 21525 give an economic yield response and also sustained acceptable even under projected worsening trade conditions in Omonada and Buno Bedele.

SUMMARY AND CONCLUSION

This trial was conducted for the two consecutive seasons on farmer's field in Omonada and Gehi woreda of Illubabore Zone, where maize is considered to be one of the major crops in the farming system especially QPM Hybrid, BHQPY545 maize. All treatments were found in the range combinations of four inter each of inter (55, 65, 75 and 85 cm) and intra (20, 25, 30 and 35 cm) spacing corresponds to population densities 33613, 39216, 47059, 58824, 38095, 44444, 53333, 66667, 43956, 51282, 61538, 76923, 51948, 60606, 72727 and 90,909 plant h-1. At all seasons and locations, due sufficient amount of rainfall at sowing period, better seedling emergence and stand establishment of maize were recorded even though planting was high labor consuming and difficult. Among the important parameters for the effects of inter and intra row spacing both seasons and locations were not show significant ($P <0.05$) interaction all parameters. Plan height, ear height, number of cobs harvested, grain yield, and biomass were significantly ($P <0.01$) influenced by both inter and intra row spacing across location and year (Table 6).

In general, in most of important parameters, the mean values were showed a linear increase with inter and inter-row spacing especially the mean grain yield showed increment cross sites and over the location from the lowest to the highest densities. The highest plant densities resulted in yield increments by 32.60% and 13.66 % with inter and intra row respectively as compared to check treatment which was lowest plant density (44,444 plants ha^{-1}) (Table 6). The farmer's perception was collected at green ear stage and the harvest period. Eight maize stand evaluation criteria were set by farmers to decide optimal plant density recommendation for BHQPY545 and from farmers decision point and current on-farm farmers interest on stalk thickness, cob size and technical feasibility, 75% of them chosen a plant density of 66,667 plants ha^{-1} (maize spacing of 75 x 20 cm) Accordingly, maize growth rate, probability of lodging, number of ears/plant and yield potential were found the most important for the maize stand evaluation criteria (Table 7). Further, based on maize stand evaluation criteria that were set by farmers (Table 7) that 75% of them chosen for a plant density of 66,666 plants/ha (maize spacing of 75 x 20 cm). Finally, the sensitivity analysis done showed that 75 cm inter and 25 cm intra row spacing with high net benefit 20584 and 21525 give an economic yield response and also sustained acceptable even under projected worsening trade conditions in Omonada and Buno Bedele. Therefore, from farmers perception and current on-farm input availability and technical, economic feasibility, a plant density of 66,666 plants/ha (maize spacing of 75 x 20 cm) taken as optimal density and recommended for the production of BHQPY545 in Omonada, Buno Bedele and other similar humid agro-ecologies of the west and southwest Ethiopia.

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