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Effect of varieties and spacing of maize on yield: A review

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Abstract
Maize has a broad array of variety. Each variety has its unique phenotypic and genotypic characters. They respond differently to different environment and different agronomic practices accordingly. In this view, this review is aimed to study the improved varieties in combination with appropriate agronomic practices of spacing at the Central Plain Zone of Kapurthala. The study showed that the hybrid variety gives more yield than the Local varieties. It also showed that the plant height, number of ear plant^{-1}, grain rows ear^{-1}, grains row^{-1}, grains ear^{-1}, grain weight, biomass yield and grain yield decreases with the decrease in spacing. But the biomass yield per plot decreases with the increase in spacing bearing long ear. The optimum plant spacing with the combination of the improved variety increases the yield of maize, thereby improving the economic returns.

Keywords: Maize, spacing, plant population, plant densities, varieties, yield

Introduction
Maize is one of the most important cereal crops in the world. It is the 3rd most major crop next to rice and wheat, where it contributes about 9% in the national food basket (Kumar *et al*. 2017) [16]. There is no cereal on the earth which has so immense potentiality like maize, therefore it is also known as 'queen of cereals' (B. Gangaiah, 2008) [31]. Globally, Maize is cultivated on about 190mha with a production of 1124mt in the year 2018-19. United States is the leading producer and exporter of Maize in the world (FAOSTAT, 2020). In India maize is grown at an area of 9.2mha with a total production of 26mt. It is mostly grown on the areas of Madhya Pradesh and Karnataka (15% each) followed by Maharashtra (10%), Rajasthan (9%), Uttar Pradesh (8%) and others (IIMR, 2020) [4].
The production of maize depends on the correct agronomic practices and right application of inputs like fertilizer and improved seed varieties to sustain the environment and increase the production. The correct efficient spacing and the suitable variety of the region are the best agronomic cultural practices which had important consideration during optimizing grain and above ground bio-mass yield (E. C. Enujeke, 2013) [26]. The most favorable plant geometry enhances the growth of maize, the sunlight interception with higher radiation use efficiency, thereby increasing the dry matter and yield (Westgate, *et. al.*, 1997) [34].
In Punjab, the state spacing recommended for maize is 60cm×22cm. In each production system, there is plant population and the varietal adaptation that exploits the utilization of available resources, allowing expression of attainable maize yield on that environment. The purpose of this review is to discuss an overview of the agronomic factors that affect the optimum maize bio-mass and yield. To review the effect of varieties and spacing on yield of maize in the Central Plain Zone, Kapurthala, Punjab, the most favorable plant spacing which enhances the growth of maize, the sunlight interception with higher radiation use efficiency, thereby increasing the dry matter and yield and the most suitable variety in the Central Plain Zone of Kapurthala are discussed herewith.

Varietal effects on maize yield
Korir, *et al*. (2013) [27] stated that the different crop varieties have different adaptability in a specific region. Adhikari, *et al.* (2021) [1] concluded that maize production can be maximized by cultivating hybrid maize variety 10V10 with the use of 220 kg N ha^{-1}in inner Terai region of Nepal. Ghimire, *et al.* (2016) [19] concluded that the Rajkumar variety performs better than Arun2 in both improved and farmers practice of cultivation with highest net return and Benefit Cost Ratio in the improved practice in in farmer's field of Maina Pokhar and Deudakala Village Development Committee in Bardiya District of Nepal. Subaedah, *et al.* (2021) [2]

concluded their study with the recommendation of the Bonanza variety at 65 DAPS to produce the greatest sweet corn cob per hectare in the South Sulawesi, Indonesia. Legesse Hidoto, (2020) [9] at three selected districts of Southern nation's nationalities and people's region conducted a field experiment during 2017 and 2018 to reveal that the maize variety BH-546 and BH-547 had higher grain yield (5.2 and 5.0 t ha-1). Adeniyan O.N. (2014) [25] revealed that the hybrid maize Obasuper showed the highest maize grain yield among the varieties (Swan 1-SR, Obasuper and Quality Protein Maize) in the Ibadan and Ikenne in South-western Nigeria.

Muhammad, *et al*. (2019) [10] revealed that the maximum plant height is shown by SB-989, maximum biological yield by Azam variety while maximum grain yield by SB-909 hybrid maize cultivar. Fahrurrozi, *et al.,* (2017) [18] recorded that the Asian Honey variety had the highest plant yield among the three sweet corn varieties (Talenta, Jambore and Asian Honey). Golla, *et al.* (2018) [15] stated that BHQPY 545 variety should be grown at Bako and Uke to produce high yield. Bhuiyan, *et al.,* (2015) [23] concluded that the suitable combination in terms of grain yield and economic return for maize cultivation was the treatment combination of BARI Hybrid Maize-5 with three irrigations at 25, 50 and 75 DAS in the fields of Sher-e-Bangla Agricultural University, Dhaka. Tahir, *et al.,* (2008) [32] found that the maximum number of grains per cob, maximum 1000-grain weight and maximum grain yield was obtained in maize hybrid HG-3740 at the region of at Faisalabad, Pakistan.

Varietal effects on maize growth

Bashyal, *et al.* (2020) [7] found that the plant height, leaf number, LAI, cob length, kernel rows per cob, kernels per kernel row, kernels per cob maize, test weight, biological yield, economic yield and harvest index of Hybrid maize was better than the Local maize under Leaf color chart (LCC) based nutrient management in the Fulbari, Dang, Nepal. Ibeawuchi, *et al.,* (2008) [33] showed that the Mean Leaf Area (MLA, cm^2), the plant height and the Dry Matter Accumulation (DMA) of the hybrid maize varieties performed significantly better than the local ones at the Teaching and Research Farm, Federal University of Technology, Owerri, Nigeria. Legesse Hidoto, (2020) [9] revealed that the maize variety 016K-SPRB and 016k-SBRH show better growth performance though BH-546 and BH-547 had higher grain yield (5.2 and 5.0 t ha-1) in the three selected districts of Southern nation's nationalities and people's region.

Fahrurrozi, *et al.,* (2016) recorded that the Asian Honey variety had the highest plant height, plant leaf-area, roots fresh-weight, weight of husked ears, and weight of unhusked ears among the three sweet corn varieties (Talenta, Jambore and Asian Honey). Alom, *et al.* (2010) [30] showed that the intercropped four rows groundnut in between paired rows of hybrid maize var. Pacific 11 among the hybrid maize (BHM-1, BHM-3, Pacific-11, and Pacific-984) showed higher total dry mater (TDM), leaf area index (LAI), crop growth rate (CGR), gross return, net return and benefit cost ratio (BCR) than the other planting systems tested in the experiment at the Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jessore.

Effect of spacing on maize yield

Agahiu AE (2020) [5] concluded that intra-row spacing had no significant effect on days to 50% tasseling and on plant height at maturity but the maize grain yield increases with wider intra-row spacing in the order of 30 cm > 25 cm > 20 cm. Alam, *et al.* (2020) [6] revealed that the maximum morpho-physiological characters, yield attributes and yield was obtained with higher composition of nutrients by using technique of 60cm×30cm (T3). Based on their study, they concluded that yield of maize increases in the order of 55cm×25cm T2> 65cm×35cm T4> 50cm×20cm T1> 70cm×40cm T5. Ukonze, *et al.* (2016) [20] recommended the 80 x 20 cm spacing for local farmers for maximum yield and economic returns. Kandil, *et al*. (2017) [17] showed that S.C. 3084 hybrid at 60 cm row width and hill spacing of 20 cm apart maximized maize productivity under the environmental conditions of Dakahlia Governorate, Egypt. Getaneh, *et al.* (2016) [22] investigation on the effect of intra (20, 25 and 30 cm) and inter-row (45, 55, 65, 75 and 85 cm) spacing with BH 660 variety had shown that thousand kernel weight and number of kernels per ear highly significantly increased with decreased inter-row spacing while above ground dry biomass yield decreased with decreased inter-row spacing. They concluded with the recommendation of spacing combinations of 65 x 25 cm.

Adeniyan O.N. (2014) [25] revealed that the plant density of 88880plants ha^{-1} gave the highest yield while the plant density of 106640plants ha^{-1} gave the minimum yield among the different plant densities [53320plants ha^{-1} (75x50cm); 88880plants ha^{-1} (90x25cm) and 106640plants ha^{-1} (75x25cm)] in both the regions of Ibadan and Ikenne in South-western Nigeria. D.R. Dawadi and S.K. Sah (2012) [28] showed that plant density of 66, 666 plants ha^{-1} produced the higher grain yield (11.19 t ha^{-1}) compared to that of 55, 555 plants ha^{-1} (9.52 t ha^{-1}). However, the stover yield increases with increasing plant density from 55, 555 plants ha^{-1} to 83, 333 plants ha^{-1}. They concluded that the plant density with 66, 666 plants ha^{-1} and 160 kg ha^{-1} N application was the most appropriate for inner terai environments of Nepal during winter season. Abuzar, *et al.* (2011) [29] concluded that planting density of 60000 plants ha^{-1} (keeping plant to plant distance of 22.70cm) is recommended for obtaining higher yield of maize in the studied region of Dera. Ibeawuchi, *et al.,* (2008) [33] recommended growing maize using plant spacing of 25 x 75cm for optimum maize grain yield in the field and an improvement for the local maize in the region of Owerri, Nigeria.

Effect of spacing on growth of maize

Alam, *et al.* (2020) [6] showed that the highest plant height, stem diameter, leaf length, number of cob $plant^{-1}$, cob length, number of grain cob^{-1}, grain weight cob^{-1}, grain yield, nutrient content was on the 60cm×30cm treatment as compared to the 50cm×20cm, 55cm×25cm, 65cm×35cm and 70cm×40cm of Maize var. BARI Hybrid Butta-09. Brad J. Bernhard and Frederick E. Below (2020) found that plants in a 51-cm row spacing yielded 0.8 Mg ha^{-1} more than when planted in 76-cm row spacing. They concluded that narrower row spacing helped mitigate crowding stress at greater plant populations by promoting phenotypic changes that consequently led to greater yield. Ihwan, *et al*. (2019) [11] showed that the leaf area index (LAI) and light interception were higher in a double row pattern of maize. Ukonze, *et al*. (2016) [20] showed that the 70 x 30cm and 60 x 40 cm spacing gave higher values of the morphological parameters than 80 x 20 cm but with regard to yield, 80 x 20 cm gave the highest average cob weight of

0.74 kg and 1000-grain weight (yield) of 0.27t/ha.

Interactive effect of varieties and spacing

Tasisa Temesgen and Teshome Kebena (2019) [12] concluded that the variety BH546 can be used at plant density of 53, 333 plants ha^{-1} and (25cm) intra-row spacing is best to get the highest green cob yield of maize in the Gulliso district of Western Ethiopia. Fathy, *et al.*, (2019) [13] recommend sowing maize cultivar TWC 352 with plant density of 30000 plants/fad., and raising nitrogen level up to 80 kg N/fad., with addition of farmyard manure to maximize grain yield/fad., under the Diarb Negm District, Sharkia Governorate, Egypt. Hasan, *et al.* (2018) [14] concluded that maize (cv. BARI hybrid maize 7) with a spacing of 75 cm × 25 cm is better for appreciable grain yield in Mymensingh of Bangladesh. Nwokwu Gilbert Nwogboduhu (2016) [21] concluded that Sammaz 17 should be planted at the planting density of 60, 000 by the farmers in the study area Ebonyi State, Abakaliki. E. C. Enujeke, (2013) [26] recommended open-pollinated variety BR9922-DMRF2 with spacing of 75 cm x 15 cm to be adopted in maize production in the study region of Nigeria for its high yielding performance.

Amin Farnia and Meysam Mansouri (2014) [24] showed that AS54 cultivar in 25cm plant density treatment had the highest cob weight and AS31 cultivar in 25cm plant density treatment had the highest cob length. However, BIARIS cultivar in 25cm plant density treatment had the highest number of row per cob and biomass yield and harvest index. The maximum 1000 grain weight was achieved in 20 cm plant density but, maximum was obtained in AS54 cultivar in 20cm plant density treatment.

Conclusion

The most important agronomic practices that require attention is the variety and plant spacing. Generally, the recommended plant variety and spacing depend on the environmental condition, plant growth resources (nutrient, water, sun light, carbon dioxide). Due to the ability to convert intercepted solar radiation in to grain yield the tallest variety of maize crop could be tolerating narrow spacing than the shortest variety. The closer or narrow spacing decreases yield of maize per plant. On the other hand, it seems to be an alternative to intensify crop production per unit land area by decreasing the spacing. Variety significantly influence the days to maturity, plant height, cob length, cob weight, cob weight per hectare, etc. The variety appropriate for a region can significantly increase the economic yield to a great extent.

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