Improved Crop Management on Open-Pollinated Maize (OPV) in The High Upland of Central Java Indonesia

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Abstract. In the highlands of Central Java, maize remains a staple food, but low yields are common due to limited use of local varieties and cultivation techniques. To address this, a study was conducted in Bojong District, Central Java, focusing on intensified maize cultivation through improved varieties, spacing, and fertilization. On-farm experiments were carried out, comparing different treatments with recommended practices. Sukmaraga maize showed the highest yields when following suggested spacing and fertilization, outperforming local yellow and white varieties significantly. The study revealed that intensification using high-yielding varieties and proper techniques could increase maize yields by 108-172% for different varieties. For local yellow and white maize, the yield increase was about 134% and 113%, respectively. Overall, adopting high-yielding varieties and improved techniques resulted in a remarkable average yield increase of 135% compared to traditional farmer practices. This research highlights the potential to enhance maize productivity in the Central Java highlands and improve food security in the region.
Keywords: maize, open-pollinated, ICM

1 Introduction

Agriculture is an important sector in the Indonesian economy, which contributes significantly to the sustainability of the food supply and people's livelihoods [1][2]. One of the main food crops in Indonesia is maize (Zea mays L.), which has a strategic role in meeting the needs for food and animal feed [3][4]. The highlands of Central Java are one of the areas that have good potential for maize cultivation, but the productivity of this crop still needs to be increased.

In Indonesia, maize production was supported by local varieties at about 20% and new superior varieties at about 80%. Among new superior varieties, 56% use open-pollinated varieties (OPV) [5][6][7][8][9]. The production area of new superior varieties is still dominated by open-pollinated varieties, which is about 48% of the total area [5]. Based on

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this fact, most farmers still used OPV, because the price of OPV seed is cheaper than hybrid.
To increase productivity and efficiency in maize cultivation, the application of appropriate fertilizer recommendations plays a crucial role [10][11]. Fertilizers are an important source of nutrients for maize plants, and their proper use can increase growth, production, and yield quality [12][13]. However, in the context of the highlands of Central Java, there is a need to review fertilizer recommendations according to the agroecological conditions and needs of OPV maize crops.

Most people in Central Java's high land consumed maize as a prime food. Kedawung village of Bojong Sub District of Tegal District is one of the high upland areas in Central Java that still uses maize as a prime food. Generally, the yield of maize in high upland is still low, as caused by local varieties use and minimum culture techniques [14][15]. Most of the farmers plant local maize with minimum crop management. So, maize yield productivity in this location is still low, about 2-3 tons/ha [14].

In this study, we aimed to analyze the application of improved crop management (ICM) by newly introduced varieties and fertilizer recommendations to composite maize plants in the highlands of Central Java. The results of this study are expected to provide a better understanding of the benefits and potential of applying fertilizer recommendations in increasing OPV maize productivity in the highlands of Central Java.

2 Methods

The assessment was conducted on the high upland area in Kedawung Village of Bojong Sub District of Tegal District Central Java, during the dry season (May-August 2017). The location of assessment is in a high upland at 900 meters above sea level (asl), with soil type Inceptisols and annual rainfall of about 3.700 mm/year [15].

The study was carried out through on-farm research, by applying 6 treatment combinations (consisting of 4 introduced varieties and 2 local varieties combined with recommended spacing and fertilization), and 1 farmer's practice as a control, with 3 farmers as replicates (Table 1). The treatments tried in this study consisted of (1) varieties (Bisma, Sukmaraga, Yellow Srikandi, Anoman, Local Yellow, Local White); (2) spacing of 75 x 20 cm; (3) recommendations for fertilizing Urea 350-425 kg/ha and Phonska 300 kg/ha. The 2nd to 4th Urea fertilization applications were used by the leaf color chart (LCC) as a fertilization guide [16]. As a control, observations were made on existing farmer practices (variety, spacing, and existing fertilizers). Details of the research treatments tried are presented in Tables 1 and 2.

Table 1. The ICM treatments applied on OPV maize in Tegal District of Central Java's high uplands

Treatment	Varieties	Fertilizer (kg ha^{-1})			Times Application of Inorganic Fertilizer	Plant Space	Seeds / Hole
		Organic	NPK**	Urea			
T1	Bisma	2000	300	350	Three times with LCC NPK (150-150-0) Urea (100-125*-125*)	70x20	1
T2	Sukmaraga						
T3	Srikandi						
T4	Anoman						
T5	Yellow Local						
T6	White Local						

T7 Control	Yellow Local	≤ 10000	0	225	Two times as farmer's habit	75x40	3-4

*) Depending on LCC, recommended dosage is 100–150 kg per hectare **) NPK Phonska (15:15:15)

Table 2. Urea 2nd to 4th Urea fertilizer application guide based on leaf color chart (LCC) on maize [16]

Time of Fertilizer Application	I	II	III	Extra
Vegetative	Leaf 3	Leaf 6-8	Leaf >10	Flowering 50%
Time	7 DAS	21-25 DAS	> 50 DAS	
Other guidance		LCC	LCC	LCC < 4
Urea	100	125-150	125-150	75

The data collected includes the 50% flowering date, 1000 grain weight, grain weight per plot, and a calculation of grain production per hectare (15.5% moisture content). The Duncan's multiple range test was used to monitor and evaluate 10 plants per treatment. For the purpose of farmers and practitioners, some criteria were also analized descriptively in order to help them identify encouraging trends in the research findings.

3 Result and Discussion

1.1 Site characteristics

The location of the assessment is the high upland area at a height of roughly 800–1000 m above sea level with fertile soil type Inceptisols (Typic Dystrudepts) [14]. Inceptisols generally have a moderate to high fertility rate. Soil fertility includes the availability of nutrients such as nitrogen, phosphorus, and potassium which are important for the growth of maize plants. However, the variation in soil fertility of Inceptisols requires soil analysis to determine specific fertilizer requirements [17].

Based on the 20-year rainfall pattern at the research location as presented in Figure 1, it was shown that the months with the highest rainfall occurred in January, February, and December. This characteristic indicates a strong rainy season at the beginning and end of the year. High rainfall of this month can provide good humidity for the growth of maize plants and has the potential to provide good yields.

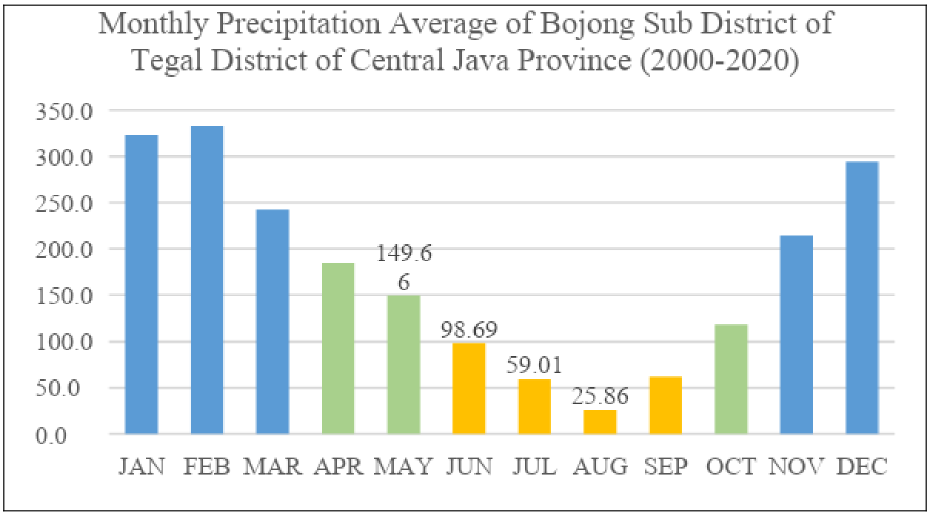

Fig. 1. Monthly precipitation in Bojong Sub District, Tegal District, Central Java [18]

The months with moderate rainfall occur in March, October, and November. Rainfall in this range indicates the continuation of a moderate rainy season, which can provide favorable conditions for the growth of maize plants. Meanwhile, months with low rainfall occur from April to September. These months belong to the dry season or periods of low rainfall. Low rainfall can cause challenges in maize growth and production due to water shortages. Proper irrigation management becomes very important in these months to ensure the plants still get an adequate supply of water.

Based on the 20-year variability of rainfall, there appears to be a significant variation in rainfall between adjacent months. For example, the difference in rainfall between May and June or July and August is quite large. This variability reflects fluctuations in weather patterns and indicates periods of temporary drought. Overall, the planting of maize in May-August presents significant variations in rainfall. Maize plants can grow well in May with relatively high rainfall [19][20]. However, from June to August, the challenge of water shortages needs to be addressed through good water management. It is important to pay attention to the water requirements of maize plants in each growth phase to maximize growth and desired yields [21][22][23][24]. To anticipate this, irrigation subsidies have been carried out in rotation by utilizing irrigation flows originating from mountain springs.

1.2 Site characteristics

Observations on plant performance were only carried out on the parameters of flowering age, 1000 grain weight, and maize shell yield. Data on the performance of flowering age, yield components, and maize plant yields are presented in Table 3.

1.2.1 Flowering age 50% (fa50)

According to field observation, the date of 50% flowering of maize is between 62 and 69 days after planting (dap), not significantly different between newly introduced varieties and local varieties. In red soil, the activity of soil enzymes in response to different chemical fertilization treatments differs in the flowering phase of maize. However, the application of fertilization levels did not have a significant effect on increasing soil enzymes. Compared to the application of chemical fertilizers, or just manure, the right combination of organic and inorganic fertilizers can increase the activity of soil enzymes [25].

The difference in flowering date of newly introduced varieties, that only less than a week, which can be brought on by the new kinds' adaption process under the new agroecology. The tasselling, pollen shedding, and silking times of maize plants are all faster at higher temperatures, while slightly slower at lower-than-optimal temperatures [26]. The little bit difference of in flowering date has shown that newly introduce varieties have a good opportunity to substitute for local varieties.

Table 3. Yield components average of OPV maize in a high upland area of Tegal, Central Java

Treatment	Varieties	Flowering Age (FA_{50})	Weight grain (WG_{1000}) (gr)	Weight grain 12m^2 (WG_{12}) (kg)	Grain yield ha^{-1} ($GY_{15.5}$) (kg)
		DMRT 5%	DMRT 10%		DMRT 15%
T1	Bisma	66 a	415 ab	8.99 b	5.741 cd
T2	Sukmaraga	66 a	504 b	9.60 b	6.138 d
T3	Srikandi	69 a	380 a	8.05 b	5.132 cd
T4	Anoman	63 a	436 ab	7.36 b	4.684 bc
T5	Yellow local	62 a	507 b	8.33 b	5.281 cd
T6	White local	62 a	388 ab	7.44 b	4.803 b
T7	Farmer existing	62 a	-	3.53 a	2.253 a
CV		-	-	5.24	9.63

1.2.2 Flowering age 50% (fa50)

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1.2.3 Flowering age 50% (fa50)

Based on Table 3 above, showing that there is no significant differences between the weight of 1000 grains of the newly introduced varieties (T1-T4) and the native varieties (T5 & T6) (DMRT 5%). The effects of fertilization and spacing can cover each other or compensate so that they are not visible on the weight of 1000 grains of maize. Based on research results, the accuracy of the amount and time of fertilization can increase the weight of a thousand seeds, on the contrary, increased plant density can decrease the weight of a thousand seeds [27][28]. Nevertheless, at DMRT 10% of the newly introduced Sukmaraga, and Yellow Local varieties with ICM had a greater grain weight than other kinds. The Sukmaraga variety has a great chance for farmers to embrace, according to this characteristic.

1.2.4 Flowering age 50% (fa50)

In general, the assessment result shows that maize yield of newly introduced varieties and local varieties with plant spacing, and fertilizer recommendations are not significantly different (DMRT 10%) in yield between one variety to another except between Sukmaraga and Anoman varieties, where Sukmaraga was higher and significantly different. The difference in yield occurred between all varieties (local and new varieties) by improved crop management (plant spacing and fertilizer recommendation) with existing farmer practice (DMRT 5%). Proper spacing can contribute to increased maize production. Optimal spacing can affect the efficiency of resource use, aeration, absorption of nutrients, and interactions between plants. In a study conducted by Singaravel [29], they found that planting maize at wider spacings increased maize seed production per hectare. Meanwhile, fertilization with the right amount and time can make a significant contribution to increasing maize production. Adequate and balanced nutrition is an important factor in the growth and development of maize plants [16]. Proper fertilization can ensure adequate availability of nutrients during the plant's growth cycle. Research conducted by Mutlu [30] showed that the right fertilization with the right dose and proportion of nutrients can increase maize production.

Sukmaraga variety with improved crop management has a tendency to be better and significantly different in yield than the white local variety, Anoman, and farmer practice at the higher multiple range test of Duncan (DMRT 15%), whereas Bisma and Srikandi varieties only perform better than the "white" local variety and farmer practice. Better and significantly different than farmer practice (DMRT 5-15%) have been local varieties (white and yellow) with better crop management.

According to maize yield of local variety at fully existing farmers practice, which only achieves of yield of about 2,25 ton/ha dry grain, improved crop management of maize cultivation through of 'open pollinated superior' variety, plant density increasing, and precise of fertilizer recommendation, maize yield can increase about 108-172%. Anoman (108%), Srikandi (128%), Bisma (155%), and Sukmaraga (172%). Sukmaraga is the variety with the highest yield increase. Additionally, the application of plant spacing and fertilizer recommendations on the indigenous yellow and white maize varieties enhanced production by roughly 134% and 113%, respectively. Improved crop management boosted production of 'open pollinated superior' and local variety maize by an average of 5,3 tons/ha dry grain, or by approximately 135% above fully existing farmer's practice.

4 Conclusion

Implementing improved crop management practices, with optimal spacing (70x20 cm) and proper fertilization (2 t/ha organic, 300 kg/ha NPK, 350 kg/ha Urea, and application timing based on leaf number and LCC, with 1 seed/ hole), can significantly increase maize yields compared to traditional farming practices (75x40 cm spacing, fertilizing only 10 t/ha organic and 225 kg/ha Urea, with 3-4 seeds/ hole).

The use of "superior open pollinated" varieties combined with better crop management practices can significantly increase maize yields, with yield increases ranging from 108% to 172%. Improved crop management practices on local varieties increased yields by 113-134% from existing farmers.

References

[1] M. Smith, M. Misiko, O. Bosch, and P. Shetty, "Contribution of Agriculture to Sustainable Development Goals in Asia and the Pacific," FAO, 2020.
[2] World Bank, "Revitalizing agriculture in Indonesia. Indonesia's rising policy priorities for 2010 and beyond," Washington, D.C.: World Bank Group, 2010. [Online]. Available: http://documents.worldbank.org/curated/en/805081468039240234/Revitalizing-agriculture-in-Indonesia.
[3] Balai Penelitian Tanaman Sereal, "Rekomendasi Pemupukan Tanaman Jagung," Balai Penelitian Tanaman Sereal. Badan Penelitian dan Pengembangan Pertanian, 2018.
[4] FAO, "Maize in Indonesia," [Online]. Available: http://www.fao.org/faostat/en/#data/QC/+.
[5] M. D. Mejaya, M. Azrai, and R. N. Iriany, "Pembentukan Varietas Unggul Jagung Bersari Bebas dalam Sumarno, Suyamto, Adi Widjono, Hermanto and Husni Kasim (Eds) Jagung, Teknik Produksi dan Pengembangan," Pusat Penelitian dan Pengembangan Tanaman Pangan. Badan Penelitian dan Pengembangan Pertanian, 2007.
[6] National Research Council (US), "The Importance of Open Pollinated Varieties of Cultivated Plants," National Academies Press (US), 2009.
[7] Z. Kusuma, S. Sumarno, and S. Bustomi, "Produktivitas Jagung Hibrida dan Jagung Varietas Hasil Seleksi di Lahan Kering Beririgasi," *Jurnal Produksi Tanaman*, vol. 5, no. 8, pp. 1617-1624, 2017.
[8] Balitbangtan, "Panduan Penelitian dan Pengembangan Jagung," Balai Penelitian Tanaman Serealia. Badan Penelitian dan Pengembangan Pertanian. Kementerian Pertanian. Republik Indonesia, 2018.
[9] E. Setyono and B. S. Purwoko, "Pendugaan Parameter Genetik dan Korelasi Sifat Hasil pada Populasi Tanaman Jagung Hibrida S0 dan Generasi S1," *Jurnal Agronomi Indonesia*, vol. 48, no. 1, pp. 67-74, 2020.
[10] I. Cakmak and G. R. C. McGrath, "Micronutrients," in *Marschner's Mineral Nutrition of Higher Plants*, Academic Press, 2011, pp. 191-248.
[11] N. K. Fageria, "Nutrient management for improving lowland rice productivity and sustainability," *Advances in Agronomy*, vol. 120, pp. 207-299, 2013.
[12] W. K. Anderson, L. D. Mitchell, and J. B. Jones, "Crop nutrient deficiency and toxicities symptoms," *UF/IFAS Extension Soil Testing Laboratory*, 2016.

[13] D. Guntoro, S. Supriyadi, and R. Wahyuningsih, "Penerapan Rekomendasi Pupuk pada Pertanaman Jagung di Lahan Kering," *Jurnal Ilmu Pertanian Indonesia*, vol. 15, no. 3, pp. 155-160, 2010.
[14] T. Prastuti et al., "Report of Participatory Rural Appraisal Survey at Kedawung Village, Bojong Sub District of Tegal District," *Balai Pengkajian Teknologi Pertanian Jawa Tengah*, 2007.
[15] BPP Bojong, "Laporan Tahunan," *Balai Penyuluhan Pertanian, Unit Pelaksana Teknis Dinas Kecamatan Bojong, Dinas Pertanian, Perkebunan dan Perhutanan Kabupaten Tegal*, 2018.
[16] J. M. C. Pasuquin et al., "Site-Specific Nutrient Management on Maize in Grobogan Central Java," *Balai Pengkajian Teknologi Pertanian Jawa Tengah (in Prepraration)*, 2005.
[17] S. W. Buol, F. D. Hole, and R. J. McCracken, *Soil Genesis and Classification*. Wiley-Blackwell, 2011.
[18] NASA, "POWER Data Access Viewer. 2022, Prediction of worldwide energy resource-agro climatology lo-cation of latitude -7.1311 longitude 109.1461," [Online]. Available: https://power.larc.nasa.gov/data-access-viewer/.
[19] M. A. Semenov, P. Stratonovitch, and U. Cubasch, "Impacts of extreme weather and climate change on wheat and maize in Europe," *Climate Research*, vol. 79, no. 2-3, pp. 99-120, 2019.
[20] R. Nisbet, D. T. Thomas, and R. L. Hill, "Impacts of drought on maize production and strategies to improve drought tolerance," *Agronomy*, vol. 10, no. 9, p. 1369, 2020.
[21] K. Pringle, S. A. Saseendran, and A. Fares, "Climate change impacts on maize productivity in tropical sub-Saharan Africa," *Theoretical and applied climatology*, vol. 133, no. 1-2, pp. 519-531, 2018.
[22] J. I. R. Edreira, M. E. Otegui, and F. H. Andrade, "Maize grain yield components and source-sink relationships," in *Achieving sustainable cultivation of maize Volume 2: Cultivation techniques, pest, and disease control*, Burleigh Dodds Science Publishing, 2020, pp. 103-136.
[23] İ. Bolat et al., "Effect of water stress at different growth stages on grain yield and yield components of maize hybrids," *Journal of Agricultural Science*, vol. 23, no. 2, pp. 161-170, 2015.
[24] D. Qu, Y. Li, and M. Hao, "Effects of waterlogging and drought stress on physiological characteristics, growth, and yield of maize," *Frontiers in Plant Science*, vol. 11, p. 586, 2020.
[25] K. Liu et al., "Response of soil enzyme activity in flowering stages of maize to long-term fertilization in red soil," *Journal of Plant Nutrition and Fertilizers*, vol. 24, no. 6, 2018.
[26] M. Liu et al., "Heat stress on maize with contrasting genetic background: Differences in flowering and yield formation," *Agricultural and Forest Meteorology*, 2022, doi: 10.1016/j.agrformet.2022.108934.
[27] Research Station of Agriculture and Natural Resources of Miandoab, "Effects of density and nitrogen fertilizer on number of ears, number of grains, and grain weight in maize cultivars," *International Journal of Biosciences (IJB)*, pp. 76–82, 2014, doi: 10.12692/ijb/4.11.76-82.
[28] G. Li et al., "Effects of close planting and nitrogen application rates on grain yield and nitrogen utilization efficiency of different density-tolerance maize hybrids," *Scientia Agricultura Sinica*, vol. 50, no. 12, 2017, doi: 10.3864/j.issn.0578-1752.2017.12.006.

https://doi.org/10.1051/bioconf/20236902010

[29] R. Singaravel et al., "Effect of plant population and nutrient management on growth and yield of maize," *International Journal of Chemical Studies*, vol. 7, no. 1, pp. 1782-1785, 2019, doi: 10.22271/chemi.2019.v7.i1a.7144.