Performance of maize under two different methods of fertilizer application in semi-arid tropic Dompu Indonesia

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Abstract. The placement of fertilizer is a crucial aspect for maximizing the nutrient uptake by maize. Maize may not produce an optimum yield and shows nutrient deficiency symptoms due to inefficient uptake of nutrients in spite of application of recommended fertilizer rates. A research was carried out to compare the method of fertilizer application for maize in five locations (five sub-districts) in the regency of Dompu, West Nusa Tenggara Province, Indonesia. The field experiment was designed in a completely randomized design (CRD), with 2 treatments for each location, and replicated 3 times. The treatments were (i) row placement of fertilizer which were given twice (P1), and (ii) broadcast application at once (P2). The results of the research showed that there was a significant difference in yield (dried maize grain) between treatment P1 and P2. The row placement of fertilizer given twice (P1) produced higher dried maize grain at all locations (average yield = 12.26 ton ha⁻¹), compared to the broadcast method given at once (P2) with average yield of 7.98 ton ha⁻¹. The yield was support with the other parameters such the height of crop, the size of cobs and the weight of above ground of dry matter.

1. Introduction

Maize (Zea mays L.) has a bright prospect in West Nusa Tenggara (NTB) Province. Although the use of maize as a staple food source tends to decrease, nationally the demand for corn, especially for the poultry feed industry steadily increase [1]. National feed consumption in 2008 reached 8.13 million tons per year, and almost 60% of poultry feed raw material is corn. Maize for animal feeding reached 3.48 million tons/year in 2004, and increased to 4.07 million tons/year in 2008 [2].

The expansion of planting area is one of the efforts to increase maize production by utilizing dry land which is widely available outside Java Island [3,4]. In NTB Province maize is one of the prime crops of three i.e. rice, maize and soybean. Government expanded the area of maize to Sumbawa Island, including Regency of Dompu which is dominated by dry land agriculture [5]. Nevertheless, due to unstable price of maize grain, it is still difficult to increase maize production at the regional level. Government has tried to encourage the farmers to consistently grow maize on their land by establishing stable price [6]. The price of maize grain is established at the beginning of season. This policy avoids grain maize price drop drastically during the harvest season. The difference of this policy with previous policy is that the government guarantees to buy farmers maize production at the approved price. This policy has effectively make farmers more enthusiastic to grow maize on their land.
Profitable maize production requires a balance fertilization. Insufficient nutrients in the soil will lower yields, while excess nutrients will lower profit margins and may damage the environment through nutrient runoff and leaching \[7,8\]. In NTB province, currently, recommended fertilization for maize is 300 kg urea and 300 kg PONSKA. Based on some farmer’s experience, with those fertilizer rates farmers may obtain yield 7 to 8 ton grain ha\(^{-1}\), and a few of them may obtain yield about 10 tons grain ha\(^{-1}\). The difference in yield was apparently due to fertilizer application method \[9\]. Most farmers would apply direct broadcast method which low cost but very low efficiency \[10,11\]. The application of this method, direct broadcast may cause inefficiency in plant nutrient uptake from fertilizer \[12\]. This resulted in nutrient deficiency or at least not sufficient to support plant growth until optimum harvest time \[13\]. Direct broadcast of fertilizers to open soil surface also caused fertilizer susceptible to be eroded away by running water during high rainfall. Fertilizer may become source of non-point pollutant to potable water \[8,14\].

Cultivation practices, such as method of fertilizer application may cause less efficient of fertilizer uptake by the crops \[12\]. Broadcast of fertilizer is less efficient compared to when fertilizer is buried at rooting zone \[15\]. The incompatibility of recommended fertilizers to maize may also occur due to the different maize variety \[8,16\]. A superior maize variety may produce higher maize grain and larger amount of biomass, hence it needs higher amount of fertilizers applied \[17\]. The optimum level of yield and biomass production, therefore can be used to indicate the amount of nutrient, especially N, P and K fertilizer should be supplied in the soil. The aims of this study are a) to demonstrate the influence of N, P and K fertilization on the growth and yield of maize crops, and b) to compare fertilizer application method, i.e. row placement and direct broadcast method.

2. Materials and methods

2.1. Location and experimental design
Field experiments were conducted during dry season at lowland which has irrigation. The sites of experiments were located in five sub-districts (Kempo, Manggalewa, Woja, Pajo and Hu’u) of Dompu Regency, West Nusa Tenggara. The lands belong to local farmers and are cultivated once with maize yearly. The field experiments were designed in a complete randomized design - CRD \[18\]. For each location, the treatments were 2 which were replicated 3 times. The treatments were row placement of fertilizer given twice (P1), and broadcast application of fertilizer given at once (P2). The total number of the treatment plots were 30. The fertilizer applied at each treatment was 300 kg urea + 300 kg PONSKA. The type of fertilizer used as source of N is Urea 45% N and PONSKA 15:15:15 meaning 15% N: 15% P\(_2\)O\(_5\): 15% K\(_2\)O.

2.2. Implementation of research
Field experiment activities started at dry season of May to August 2018. Land preparation was started 30 days before planting. No tillage was applied to the soil. This method was conventionally conducted by farmers. Trial plots were made with a size of 10 x 10 m. The distance between plots was 0.50 m and separated by drainage channels with width 30 x 20 cm. Crop spacing between rows was 70 cm while distance within rows was 20 cm. Thus there were 714 plants in each plot.

The variety of maize chosen was a hybrid species, named BISI 2. In P1 treatment, the fertilizers was applied at 50% of total rates as basal fertilizer and the rest was applied at 40 days after sowing (DAS). While for P2, whole fertilizers (100%) was broadcast at the same time with the day of sowing (0 DAS). The fertilizer for P1 was put within row with a distance of 5 cm from the sowing holes, and at a depth of row which was 5 cm from soil surface. While for P2, the fertilizers were broadcast over the land.

Protection of maize crop from diseases is done by soaking the seeds in a concentrated solution of fungicide before the seeding is done. Protection of maize from pests (especially worms and grasshoppers) was done by spraying insecticides. Protection of crop from weeds is done through application of appropriate herbicides or it will be controlled manually if the amount of weeds is not so significant.
2.3. Observed parameters and statistical analysis
The parameters observed were weight of dried maize grain, dried husk, dried hump and dried maize stalk. Besides, it was also observed the soil parameters including soil pH (glass electrode) [19], soil organic matter content (Walkley and Black), total soil N content (Kjeldhal method), Bray-I P and exchangeable K using extract Ammonium acetate. The results of experiment was analysed statistically using analysis of variance (ANOVA). If there were difference of means between two treatments is tested with t-test at 95% of confident level [18].

3. Results and discussion

3.1. Soil and hydrometeorology
Dompu Regency is the major of maize production in NTB province. Maize is grown on dry land during the rainy season and on wetlands (rice fields) after the rainy season. However, most of the rice fields in Dompu are rainfed. Land without rain cannot be planted with maize because of almost no rain during the dry season.

The climate of the Dompu region is categorized as semi-arid tropics (SAT). This climatic type is characterized by a distinct dry season and a short rainy season and almost no rain during the dry season [13]. In the classification of Indonesian climate which is based on number of wet months (WM) and dry months (DM) [20], the climate in Dompu is included into D4 climate type (3-4 WM and> 5 DM). The amount of annual rainfall ranges from 1100 mm to 1200 mm. Low annual rainfall and hilly topography causes not much water to be held as surface water. There are very few rivers which have water flows during the dry season (intermittent river), most rivers are short in length and has water flows only during rain falls or sometimes after the rain falls. That is why the irrigation area supplied with surface water is very small compared to the total amount of rice fields in Dompu. Fortunately, in some locations of the rice fields there is enough ground water being pumped with a water pumping machine. The locations of planting maize using groundwater irrigation are Kempo, Manggalewa and Hu’u, while in other locations (Woja and Pajo) it is used surface water (irrigation) which is stored for a while in small ponds (local name is small embung).

The soils of the rice fields used for these field experiments have medium depth (± 60 cm). The top layer has around 15 cm to 20 cm thick, while the lower layer (subsoil) is ± 40 cm thick. The soil surface is wrinkled or there are crack with 1-2 cm wide 10 cm depth. In Soil Taxonomy these soils belong to the Inceptisol order, which is the soil that has just developed. The evidence is the existence of the Bw horizon, which is a B horizon which is having slightly different colour compared to the A horizon above it. Table 1 shows the chemical properties of topsoil of land used for field experiments.

| No. | Location (Sub distric) | C-Organic (%) | N Total (%) | P Available (ppm) | K Available (me %) | pH (H2O) |
|-----|------------------------|---------------|-------------|-------------------|--------------------|----------|
| 1   | Hu’u                   | 1,47 (L)      | 0,10 (L)    | 6,8 (L)           | 0,45 (M)           | 6,8      |
| 2   | Pajo                   | 1,52 (L)      | 0,20 (L)    | 10,8 (M)          | 0,65 (H)           | 6,7      |
| 3   | Woja                   | 1,38 (L)      | 0,20 (L)    | 7,5 (M)           | 0,30 (L)           | 6,8      |
| 4   | Kempo                  | 1,43 (L)      | 0,15 (L)    | 12,4 (H)          | 0,42 (M)           | 6,6      |
| 5   | Manggalewa             | 1,55 (L)      | 0,12 (L)    | 9,5 (M)           | 0,45 (M)           | 6,8      |

Note: L = low, M = medium, H = high

From the table 1, it is shown that the pH, C-organic and total N is almost the same for all location. The pH is neutral, while C-organic and total N were in low level. Available phosphorus (P-Bray I) and exchangeable K were variable from low to high level. However, with application of P and K at 45 kg P2O5 ha-1and 45 kg K2O ha-1 contain from 300 kg PONSKA will avoid the difference in yield due to the difference in initial P and K content of soils.
3.2. Grain yield and above ground dry matter of maize

The results of the experiment showed that there was a significant difference in yield (dried maize grain) between treatment (P1) and (P2) e.g. between the treatments of 300 kg urea + 300 kg PONSKA with row placement applied twice compared to the treatment of 300 kg urea+ 300 kg PONSKA applied with direct broadcast over soil surface at once. The dried maize grain weight, as the main parameter, was greater at treatment P1 compared to P2. Table 2 shows that an average grain yield of 12.30 ton ha\(^{-1}\) of P1 treatment compared to 6.18 ton ha\(^{-1}\) of P2 treatment.

**Table 2.** The weight of dried maize grain in 5 locations as affected by the methods of fertilizer placement.

| No | Location(sub-distric) | P1 (ton/ha) | P2 (ton/ha) |
|----|-----------------------|-------------|-------------|
| 1  | Hu'u                  | 12.20**     | 8.30        |
| 2  | Pajo                  | 11.90**     | 7.69        |
| 3  | Woja                  | 12.50**     | 7.88        |
| 4  | Kempo                 | 12.30**     | 8.18        |
| 5  | Manggalewa            | 12.50**     | 7.87        |
|    | Average               | 12.26**     | 7.98        |

Note: ** the number is very significant difference compared to next number

The grain result was in line with the weight of corn husk and hump. Tabel 2 and Tabel 3 show the results of corn husk and hump. The weight of both maize husk and hump of P1 were greater that those of P2.

**Table 3.** The dry husk weight of maize as it is removed from maize cob in 5 sub-districts as affected by the methods of fertilizer placement.

| No | Location (Sub distric) | P1 (ton/ha) | P2 (ton/ha) |
|----|------------------------|-------------|-------------|
| 1  | Hu'u                   | 0.79        | 0.64        |
| 2  | Pajo                   | 1.00        | 0.79        |
| 3  | Woja                   | 0.93        | 0.79        |
| 4  | Kempo                  | 0.93        | 0.86        |
| 5  | Manggalewa             | 0.86        | 0.64        |
|    | Average                | 0.90        | 0.74        |

Lower grain yield with broadcast method of fertilizer application was due to inefficient use of fertilizer. This caused low amount of nutrient that is able to be up-taken by crop [12]. This further caused deficiency of some nutrients mainly nitrogen and phosphorus. This eventually produced low grain yield [8]. Fertilizers that spread to dry soil surface also caused fertilizer susceptible to be eroded away by running water during high rainfall. Fertilizer may become source of non-point pollutant to potable water [14]. Vitch and Randall stated that direct broadcast should not be applied to N fertilizer for maize crop with no tillage because nitrogen contained fertilizer soon will be volatilized [21]. Engel et. al. stated that direct broadcast method of fertilizer application could cause that the fertilizer on soil surface is eroded by water runoff when storm in coming [22]. This result in nutrient is far away from root zone. Broadcast of fertilizer is less efficient compared to when fertilizer is buried at the rooting zone [15]. The incompatibility of recommended fertilizers to maize may also occur due to the different maize variety [8,16].

Chen et. al. agreed that row or banded placement is one of the strategy required to increase nutrient uptake by corn [23]. Putting the fertilizers near root zone prevents crop from nutrient deficient during growing period [24].
Table 4. The dry hump weight of maize as the grain was removed from maize cob in 5 sub-districts as affected by the methods of fertilizer placement.

| No | Location(Sub distric) | P1 (ton/ha) | P2 (ton/ha) |
|----|-----------------------|-------------|-------------|
| 1  | Hu’u                  | 2.21        | 1.93        |
| 2  | Pajo                  | 2.36        | 2.00        |
| 3  | Woja                  | 2.29        | 2.00        |
| 4  | Kempo                 | 2.14        | 1.93        |
| 5  | Manggalewa            | 2.14        | 1.86        |
|    | Average               | 2.23        | 1.94        |

The dried maize grain results were also in line with dry maize stalk. Average weight of dried maize stalk with treatment (P1) was greater compared to that of with treatment P2. Table 4 shows the dried maize stalk weight as affected by the methods of fertilizer placement. Nutrient sufficiency with row placement treatment will cause continuity of maize growth from vegetative to reproductive stages. This allows the formation of cobs with optimum size and grain filling during reproductive period. A superior maize variety may produce higher maize grain and larger amount of biomass; hence it needs higher amount of fertilizers applied [17]. The optimum level of yield and biomass production, therefore, can be used to indicate the amount of nutrient, especially N, P and K fertilizers should be supplied in the soil [25].

Table 5. The dried maize stalk weight of 5 sub-districts as affected by the methods of fertilizer application.

| No | Location(Sub distric) | P1 (ton/ha) | P2 (ton/ha) |
|----|-----------------------|-------------|-------------|
| 1  | Hu’u                  | 5.71        | 3.71        |
| 2  | Pajo                  | 8.29        | 3.93        |
| 3  | Woja                  | 6.07        | 4.29        |
| 4  | Kempo                 | 7.50        | 5.00        |
| 5  | Manggalewa            | 6.07        | 4.64        |
|    | Average               | 6.73        | 4.31        |

4. Conclusion

between the P1 treatment (300 kg urea + 300 kg PONSKA with row placement, twice application) and P2 treatment (300 kg urea + 300 kg PONSKA with broadcast in once application). The dried maize grain of the P1 treatment was 12.26 ton ha-1, which was higher than treatment P1 with 7.98 ton ha-1. The yield was supported with the other parameters such the weight of cobs and the weight of above ground dry matter. The total weight of above ground biomass minus cobs was 6.73 ton ha-1 in P1 and 4.31 ton ha-1 in P2.

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