AAB BIOFLUX

Advances in Agriculture & Botanics-
International Journal of the Bioflux Society

Different tillage and maize grass intercropping on root systems, growth and yield of rainfed maize (*Zea mays* L.)

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Abstract. The study was conducted in a year period in rainfed area of Lampung province Indonesia. Objective of this study was observe the effect of tillage and maize grass intercropping in the rainy season to succeeding dry season on root systems, plant growth and yield of the rainfed maize. Three tillage methods (viz. no tillage, conventional tillage and deep tillage) and intercropping (viz. sole maize, maize + clump grass (*Vetiveria zizanoides*), elephant grass (*Penisetum purpureum*) and lemon grass (*Cymbopogon citratus*) was tested in split plot design with three replications. The study obtained the results that lateral root distance, root dry weight and dry biomass were greater in maize intercropped than sole maize plots in all tillage methods. There had an insignificantly effect on yield due to tillage and maize intercropped. Maize could be intercropped with clump, elephant and lemon grasses without effect on the maize yield in succeeding dry season.

Keywords: tillage methods, maize + grass intercropped, root systems, plant growth, yield.

Introduction. Maize is one of the most important economic crops, which ranks second to rice in Indonesia (Maamun et al 1999; Undang 2003; Swastika et al 2004). Maize is grown for both human consumption and animal feed (Maamun et al 1999; Swastika et al 2004) about 79% and 21%, respectively (Swastika et al 2004). According to estimates by Kasryno (2002), future demand for maize for the feed industry will be steadily increasing compared to food industry. Maize is planted on both dry lands and rain-fed lowlands, and only a small portion is grown on irrigated lowlands as double cropped maize. Water availability during dry season would not cause serious draw back in maize production, but long dry spells during rainy season connected with long drought would affect dry season maize production. However, maize production has not been able to meet the growing domestic demands for maize in Indonesia so far (Maamun et al 1999; Swastika et al 2004).

Developing appropriate technology to improve maize productivity and crop yield to dry season is a greater challenge then that for wet season. It is no doubt that research to improve land productivity and crop yield in rainfed areas should consider the condition specific to different localities. Although, some farmers practices such as use of appropriate maize cultivars, appropriate tillage method and using soil moisture conservation (mulching etc.) to hold more water could improve crop yields, handling moisture deficit during long dry seasons could not be achieved unless water retention in the soil profile where root systems develop is improved.

The study was started in rainy season to improve the soil water holding capacity by growing grasses and it would be useful for succeeding crop in dry season as a main emphasize. This is a strategy to develop deep soil layer, often denoted by horizons would be the growing of deep rooted crops with a high root biomass production in the wet season along with the wet season crop assuming the competition between the two species for water would be minimum and the other resources such as nutrition could be externally managed. Much less study has been done on maize grass intercropping to improve development of maize root growth in rainfed areas during a year growing seasons. This paper is present to observe effect of tillage and intercropping in rainy season and the impact on root systems, plant growth and yield in succeeding dry season.

Materials and Methods. This study was conducted in Metro District of Lampung province, Indonesia, during December 2005 – August 2006. According to USDA, the soil texture of the study site is sandy clay loam with friable consistency. In dry season, the pH (H_2O) was measured in average of 0-30 and 30-70 cm soil depth and the value about 5.16, the period from May to August 2006. The location received an average of monthly rainfall of 441 mm in the wet season and 98 mm in the dry season. In Indonesia, rainfall intensity lower than 100 mm, 100-200 mm and more than 200 mm per month are indicated dry, transition and rainy seasons, respectively.

The study was evaluated effects of tillage and intercropping with grass in the rainy and the impact on root systems, plant growth and yield of rainfed maize in dry seasons. The field was not tilled within 3 years back and citrus as the last crop was planted. The experimental treatments were composed of combinations of three tillage methods [viz. no tillage, conventional tillage (20 cm soil depth) and deep tillage (30 cm soil depth)] as main plot and four intercroppings [viz. sole maize, maize + lemon grass (*C. citratus* [Linnaeus, 1753] (A.P. De Candolle) Stapf), maize + clump grass (*V. zizanioides* [Linnaeus, 1753] Nash) and maize + elephant grass (*P. purpureum* [Richard, 1805] Schumacher)] as sub plot in the rainy season. BISI-9 as a hybrid variety was used in this study. For conventional and deep tillage, the land was tilled by tractor (disk ploughing) and the disk was set up driving to a given depth i.e. 20 and 30 cm soil depth. The rest of crops after harvesting of maize in the rainy season were incorporated into the soil by minimum tillage (about 10 cm soil depth by using hoe) i.e. maize stalk, leaves, roots and also shoots of grasses as organic matter sources in all plots including in no tillage plots. In the dry season sole maize was grown in preceding tillage methods and intercropping plots. Both studies were arranged in split plot design with three replicates.

In conventional tillage, the land was plowed once, harrowed twice and levelled using a tractor with standard implements. Deep tillage was adopted using a tractor to a depth of 30 cm. For No tillage method glyphosate was applied at the rate of 480 a.i. g l^{-1} to control weeds. The plots of conventional and deep tillage treatments were finally prepared as ridge (15 cm height) and furrow system distance between two adjacent ridges of 75 cm. Three maize seeds were dibbled on the ridge on an intra-row spacing of 25 cm. Seeding rate was 15 kg ha^{-1}. In no tillage plots, the same number of maize (M) seeds was directly dibbled on the flat surface with same inter and intra-row spacings and maintain the same plant population. In intercropping treatments the second crops i.e. clump grass (C) (*V. zizanioides*), elephant grass (E) (*P. purpureum)* and lemon grass (*C. citratus*) (L) were established in the furrow with an intra row spacing of 75 cm.

Each plot received N, P and K at the rate of 65, 28 and 14 kg ha^{-1}, respectively, using urea (46% N), triple super phosphate (19.8 % P) and muriate of potash (50% K), respectively as a basal dressing, seven days after sowing. The seedlings were thinned out to one plant per hill at 14 days after emergence. At second top dressing 65 kg $ha^{-1}$of urea was applied 6 weeks after sowing. There was neither any pest nor diseases observed during growing period. Weeds were manually controlled every 2 weeks until silking.

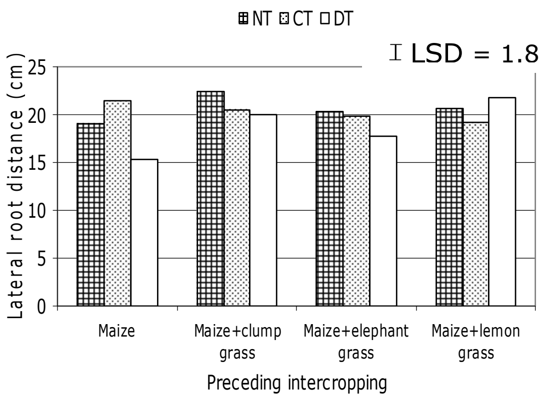
Roots data were gathered from one randomly selected representative plant in each plot by digging a trench to 50 cm in width and depth around the selected plant. Soils in one side of the plant were dug first and the lateral and depth of root growth in rectangular to row were measured and recorded. Then the other side was dug, and similar observations were made. All the roots were collected during digging the pit around maize plant. The plant was finally uprooted, soil was washed out, and roots were separated. Total root length was determined using root intersection method after air dried. Later, the roots were oven-dried to 80 ^{0}C and dry weight was recorded (Bohm 1979).

Crop development data were observed such as plant height, leaf area, dry weight of plant biomass and yield. Yield components of maize were gathered from 10 consecutive plants within a single maize row out of 12 rows leaving two corners most rows and 50 cm strip from either ends of each plots as border area. Plant height was measured from the ground level up to the collar of the flag leaf (Flint-Garcia et al 2003). Leaf area was estimated by using leaf length and breadth (McKee 1964), and leaf area index (LAI) was computed dividing leaf area by land area subtending the corresponding leaf area.

All data were analyzed by using Analysis of Variance procedure (Steel & Torrie 1980). Treatment means were compared using Fisher's Protected LSD method.

Results and Discussion. There were significant interactions among tillage and intercropping on lateral root distance and root dry weight but no significantly effect on root depth and total root length. In the dry season, there was significant interaction among preceding tillage and intercropping on dry biomass but no significantly effect on plant height, LAI and yield.

Root Systems. Lateral root distance had lower values in preceding all intercropping under deep tillage plots except in preceding maize + lemon grass plot (Figure 1a). In preceding maize + clump grass plots had a highest lateral root distance of 22.5 ± 3.2 cm under no tillage and the lowest of 15.3 ± 1.6 cm in preceding sole maize under deep tillage plot. In preceding deep tillage plots had the lowest root dry weight in all intercropping (Figure 1b). In preceding maize + lemon grass under conventional tillage plots obtained the highest root dry weight than other treatments.



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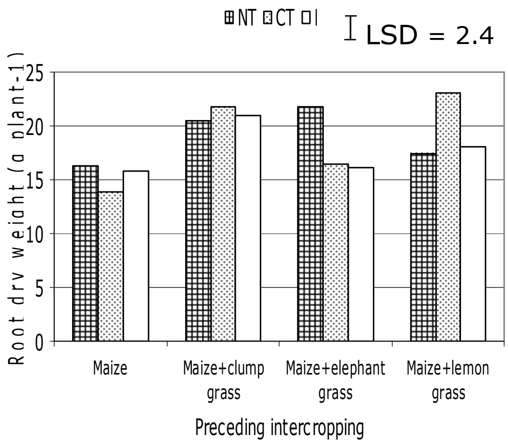


b

NT – no tillage, CT – conventional tillage, DT – deep tillage.

Figure 1. Effect of preceding tillage and intercropping in the dry season: a) Lateral root distance, b) Root dry weight.

Root depth ranged from 24.7 ± 0.5 cm in preceding no tillage plot to 27.7 ± 0.4 cm in preceding conventional tillage plot and from 18.5 ± 0.4 cm in preceding sole maize plot to 21.1 ± 2.3 cm in preceding maize + clump grass plot (Table 1). Total root length among tillage methods was higher in preceding conventional tillage plot (2468.8 ± 286.6 cm) and among intercropping, in preceding maize + clump grass plot (2527.3 ± 69.2 cm) (Table 1). In succeeding dry season there was no single effect of preceding tillage and intercropping on maize root systems. Preceding tillage would not have effect to succeeding cropping season on root systems. Yet, there was interaction of preceding tillage and intercropping on lateral root distance and dry root weight. The lateral and spread of root systems depend on both heredity and environment (Kramer & Boyer

1995). In current study, root growth is greatly affected by soil environment factor due to intercropping maize and grasses. Effect of tillage in the preceding season could not furnish continuously effect to succeeding maize crop on root depth and root length (Table 1).

Combination of preceding intercropping obtained the higher lateral root distance and root dry weight than preceding soil maze under all tillage methods (Figure 1a and 1b). Liedgens et al (2004) reported that single stands of maize developed much lower root densities in time and space compare with ryegrass intercropping. Availability of grasses from preceding season improved soil physical condition and affects the ability of roots to grow. Preceding grasses was slashed by which it could be possible grass root systems still in growth and promote the suitable soil condition for maize root systems. Prihar et al (2000) mentioned, deeply rooted grasses indicate conditions favourable for cultivated plants of similar habit. The continued growth of grasses throughout the season indicates a long favourable growing season uninterrupted by a deficiency of soil moisture, so the water is enough for both grasses and maize.

However, deep root penetration still had limitation due to the low pH and intercropping with grasses might not facilitate to improve maize root growth deeper (Table 1). As mentioned above in preceding season, limitation for root to grow under low pH could be possible because of high of Al as a common condition in acid soils. Al toxic subsoil due to low pH is often more common barriers to root development (Sanchez 1976; Horst et al 1997; Jayasundara et al 1998).

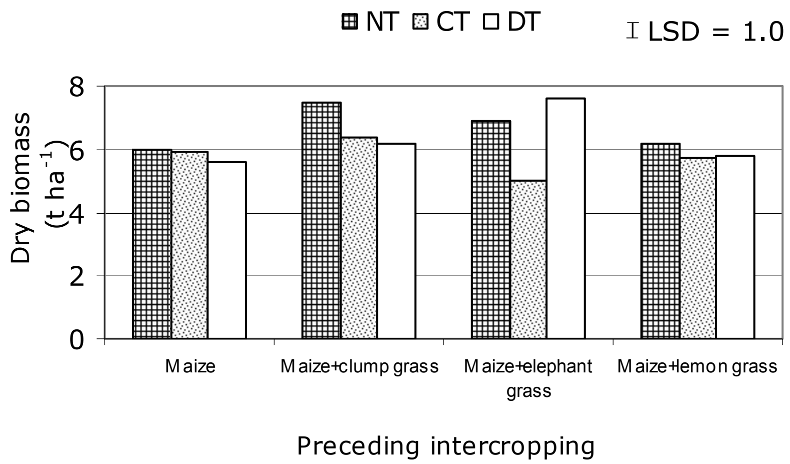
In general, preceding maize and grass intercropping would improve the succeeding maize root systems. Even though the root systems could not reach the deeper soil profile but the root length resulted greater in preceding intercropping plots than preceding sole maize plots. High root length indirectly increased root density and resulted adequate contact with the solid and liquid phases of soils. High root density may have capacity to uptake water and nutrient and improve plant development (Passioura 1999; Abu-Hamdeh 2003).

Table 1

Plant growth, root systems and yield of rainfed maize as influenced by preceding tillage and intercropped in the dry season

Treatments	Plant height (cm)	LAI	Root depth (cm)	Total root length (cm)	Yield (t ha^{-1})
Preceding Tillage					
No tillage	143.6 ± 8.4	3.7 ± 0.4	24.7 ± 0.5	2368.8 ± 241.2	2.2 ± 0.4
Conventional tillage	149.7 ± 5.6	3.3 ± 0.2	27.7 ± 0.4	2468.8 ± 286.6	2.2 ± 0.2
Deep tillage	154.3 ± 6.3	3.5 ± 0.3	25.4 ± 2.0	2300.5 ± 210.0	2.4 ± 0.5
LSD (0.05)	ns	ns	ns	ns	ns
Preceding Intercropping					
Sole maize	148.6 ± 10.1	3.4 ± 0.4	18.5 ± 0.4	2240.9 ± 219.2	2.1 ± 0.2
Maize+clump grass	154.5 ± 7.2	3.6 ± 0.3	21.1 ± 2.3	2527.3 ± 69.2	2.4 ± 0.6
Maize+elephant grass	146.2 ± 6.5	3.5 ± 0.6	19.2 ± 2.7	2376.3 ± 219.7	2.3 ± 0.2
Maize+lemon grass	147.5 ± 8.1	3.4 ± 0.8	20.3 ± 1.0	2373.0 ± 377.5	2.3 ± 0.1
LSD (0.05)	ns	ns	ns	ns	ns
CV (%)	9.0	13.8	7.7	13.0	11.0

Plant Growth and Yield. Plant height ranged from 143.6 ± 8.4 cm in preceding conventional tillage to 154.3 ± 6.3 cm in preceding deep tillage and from 146.2 ± 6.5 cm in preceding maize + elephant grass plots to 148.6 ± 10.1 cm in preceding sole maize plots (Table 1). In preceding maize + elephant grass and maize + clump grass under deep tillage and no tillage had a higher dry biomass of 7.6 ± 0.5 t ha^{-1} and 7.5 ± 0.5 t ha^{-1}, respectively (Figure 2) but lower in other intercropped under all tillage methods. In general, dry biomass under preceding no tillage in all intercropped had higher value than other tillage methods.



NT – no tillage, CT – conventional tillage, DT – deep tillage

Figure 2. Dry biomass as influenced by preceding tillage and intercropped in the dry season.

LAI had no different effect due to preceding tillage and intercropping. The value ranged from 3.3 ± 0.2 in preceding conventional tillage plots to 3.7 ± 0.4 in preceding no tillage plots. In preceding intercropping plots, the value ranged from 3.4 ± 0.4 in sole maize plots to 3.6 ± 0.3 in maize + clump grass plots (Table 1). Even there had no significantly effect due to tillage and intercropping, in preceding deep tillage plot had a higher grain yield 2.4 ± 0.5 t ha^{-1} than other tillage methods and in preceding maize + clump grass plots of 2.4 ± 0.6 t ha^{-1} than other intercropping (Table 1).

The higher LAI in no tillage shows exposure of maize plants to no stressful conditions compared to both conventional and deep tillage methods. Even though there was no significant different on plant height, in preceding intercropping plots had little bit competition indicated by the higher plant height in preceding sole maize plots.

This shows that maize in both sole crop and intercrops did not exposed to different stresses due to tillage effects or to competitive effects to affect two yield components that are critical in determining the final yield of maize. The results also indicate that growing maize either in intercropping with clump grass, elephant grass and lemon grass or as a sole crop in rainy season will not make a difference to succeeding maize yield in the dry season.

In the current study, there were no significant differences in grain yields due to cropping patterns. This shows that growth and yield of maize have not been affected by intercropping with grasses. As far as maize yields are not affected in the dry season, any practice that would bring long term benefits and would be acceptable to maize growers. Formation of large, stable and continuous pores in the soil profile, decrease in soil bulk density, and increase in infiltration rates and hydraulic conductivity are resulted due to grasses with dense root systems (Prihar et al 2000), hence it would greatly influence root growth and access to water and nutrients (Kramer & Boyer 1995) of not only in the currently growing crop, but also in the succeeding crops. This will provide opportunities for farmers to grow maize in the following dry season and to avoid extreme water stress and its adverse effects causing low yields.

Conclusions. Effect of preceding intercropping had no significantly effect on root depth and total root length in the succeeding season. However, lateral root distance, root dry weight and dry biomass had greater in preceding intercropped plots than sole maize plots in all preceding tillage methods. Greater lateral root distance resulted by preceding maize clump grass intercropped under no tillage. Whereas, root dry weight and dry biomass was greater by preceding deep tillage methods in preceding maize lemon grass and maize elephant grass intercropped, respectively than other treatments. There was no significantly effect on yield due to preceding tillage methods and intercropping. Therefore, maize could be intercropped with clump, elephant and lemon grasses without interfere the succeeding maize yield in dry season.

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Received: 12 March 2011. Accepted: 10 April 2011. Published online: 26 April 2011.

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How to cite this article:
Ahadiyat Y. R., Ranamukhaarachchi S. L., 2011 Different tillage and maize grass intercropping on root systems, growth and yield of rainfed maize (*Zea mays* L.). AAB Bioflux **3**(1):33-38.