Evaluation of Pigeon Pea (Cajanus cajan) Cover Cropping and “No-till” as a Soil and Crop Management Practice in Corn (Zea Mays) Areas of Isabela, Philippines

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Abstract Experiments were conducted to assess and evaluate the effects of pigeon pea (Cajanus cajan) cover cropping and no-till practice on corn (Zea Mays) yield, surface runoff and soil erosion. The experimental site was a grassland with a uniform slope of 10% and low fertile clay loam surface soils located at the Soil and Water Conservation Station, Brgy. Baligatan, Ilagan, Isabela, Philippines. There were 3 treatments, namely: fallow + till (F+T), fallow + no-till (F+NT), and pigeon pea (Cajanus cajan) + no-till (PP+NT). Pigeon pea was grown during the period of February to May, 2008, then cut and mulched on the soil surface before corn planting. After corn harvest in September, the second corn cropping was conducted during the period of November, 2008 and February, 2009. Organic matter content in the PP+NT treatment increased significantly during the experimental period unlike that for the other treatments. PP+NT also led to a lower maximum soil temperature at a depth of 5 cm compared with the other two treatments. PP+NT also led to a soil water depletion behavior in deeper soil horizons during the lull period probably due to deep root penetration and active photosynthesis during the maturation period. The 20 hill-based corn yield for PP+NT was improved by almost 1 t ha⁻¹ compared with that for F+T, although the values were not statistically significant, probably due to the nutrient contribution from pigeon pea biomass. PP+NT also contributed to reducing soil runoff and soil erosion, particularly during peak rainfall events. Hence, pigeon pea cover crop in combination with no-till, with proper management, was found to be effective in ensuring sustainable corn production in sloping lands by improving crop yield, minimizing soil erosion and nutrient loss.

Key words: Luzon Island, Soil conservation, Soil water and temperature, Water runoff

Introduction

Corn is the second most important cereal in the Philippines, with Isabela Province as the highest producing province (Reyes et al., 2007). Mono-cropping of corn is predominantly practiced and consists of wet season cropping from May-August and dry season cropping from November-February. While the main factor for Isabela’s high corn production is associated with its extensive broad river valleys and flood plains, hilly areas are also currently being cultivated to corn, resulting in high runoff and severe soil erosion. These are further aggravated by high rainfall intensities during the rainy season, reduced vegetative cover associated with anthropogenic activities, inappropriate management practices, and poor adaptation of technologies due to the lack of location-specific evaluation of these technologies.

In order to obtain both sustainable production and soil conservation, FAO has strongly promoted conservation agriculture (CA) since long time. CA is characterized by three principles (Reicosky, 2008): 1) minimum soil disturbance, 2) continuous residue cover, and 3) diverse rotation and/or cover crops. CA-based cropping systems are widely adopted and multiple effects such as soil erosion control, high rainwater efficiency, soil quality improvement, etc. are well recognized (Thierfelder et al., 2012; Abera et al., 2012; Johansen et al., 2012; Nagumo et al., 2006). For the diverse cropping systems, many crops have been used as cover crops for CA.

Pigeon pea is one of the suitable cover crops that can be used for corn cultivation. Known as “kadyos” in the Philippines, pigeon pea is a minor crop that is usually grown in small farm areas. It grows even in hilly areas where many other crops are likely to fail. It is drought-resistant, deep-rooted and can fix nitrogen from the air into the soil. As a cover crop, according to Dar (2009), Director of the International Crop Research Institute for the Semi-arid Tropics (ICRISAT), it is useful for increasing soil fertility, in preventing soil erosion, and in suppressing weeds in upland farms (Agri-business Week, 2009).

Previous studies showed that there are three options of pigeon pea introduction; 1) use as annual plant, 2) as green manure, and 3) perennial tree. As annual plant, it is often intercropped with main crops.
In this case, intercropped pigeon pea is harvested or its residue is mulched for the next cropping. Ngwira et al. (2011) reported that intercropping of pigeon pea with corn increased maize grain yield, compared with maize mono-cropping and concluded that intercropping maize and pigeon pea under CA offers a win-win scenario due to crop yield improvement and favorable economic return. Baldé et al. (2011) showed that the land equivalent ratio (LER) for maize grain yield and biomass production for maize/pigeon pea intercropping system was particularly high, reaching values of 1.72 and 1.74 in 2007-2008 and 2.02 and 2.03 in 2008-2009, respectively.

If there is a fallow period, pigeon pea is also used as green manure and the plant body is mulched for the next cropping in CA systems. According to the study conducted in Brazilian Cerrados, Maltas et al. (2009) showed that replacing the bare fallow period by a cover crop can induce a positive effect on N uptake and yield of the following maize cropping. Among the four treatments with a combination of either sole or two cover crops, sole pigeon pea or sole sorghum cover cropping resulted in the highest subsequent corn yield.

The last option is alley-cropping using perennial trees (Moura et al., 2008; Moura et al., 2010; Aguiar et al., 2010), which have been mainly studied in Brazil. Between the pigeon pea rows, the main crops are planted and pruned materials are used as mulch under no-till practices. Once pigeon pea alley is established, a higher organic matter turnover to the soil is expected since the pigeon pea tree can grow over a longer period of time and is expected to produce more biomass. Moura et al. (2008) tested alley-cropping systems under no-till practices for the corn yield productivity with different combinations of trees, such as Clitoria + Pigeon pea (C+PP), Acacia + Pigeon pea (A+PP), Leucaena + Clitoria (L+C), Leucaena + Acasia (L+A), Leucaena + Pigeon pea (L+PP). Among them, L+A alley-cropping increased 3.5 times corn productivity, compared with the control without residue. Grain yield for A+PP also increased 1.8 times compared with that of the control, although it was less effective. These results indicate that the effects of mulch using pruned materials depend on the properties of trees such as C/N ratio (Aguiar et al., 2010). Alley cropping under no-till practices is expected to contribute to soil and water conservation more efficiently than the other options due to the presence of trees. However, comprehensive studies on yield potential and soil and water conservation have not been conducted. This is especially important when hilly land which is susceptible to soil erosion, is used for cropping.

The purpose of the present study was to evaluate the effect of pigeon pea cover cropping and continuous use as alley-cropping on corn productivity and soil erosion and water runoff under no-till condition on sloping land, in the Isabela province, Luzon island, the Philippines.

Materials and Methods

Soil Characterization and Analysis

The study site was located at the Soil and Water Conservation Station, Baliwag, Bulacan, Isabela in the northeastern part of Luzon Island, Philippines. Prior to the initiation of the tillage operation (pre-experimental period), 12 undisturbed core samples (4 for every horizon/layer) and 4 disturbed samples from different layers (0 - 16 cm, 16 - 31 cm, 31 - 59 cm, and 59 - 95 cm) were collected for laboratory analysis. The soils at the study sites were analyzed in terms of available water, saturated hydraulic conductivity (SHC), pH, organic matter (OM) content. Subsequently, soil sampling (0 - 15 cm, composite samples with three points in each plot) and analyses were undertaken before the start of the cropping in February 2008 and after harvest in September 2008 and February 2009. Saturated hydraulic conductivity (SHC) was measured by the constant head method with undisturbed core samples. Field capacity was measured at -6 kPa with a pressure extractor, while the lento-capillary point at -98 kPa, using a cellulose acetate membrane method. The amount of easily available soil water was determined as the difference in volumetric water content between the field capacity and the lento-capillary point. Solid phase was determined using three-phase method (DIK-1120, Daiki rika Co., Japan). Organic matter content was determined by Walkly-Black method. Total Nitrogen content was determined by the Kljedhal method. Available P content was determined by the Bray-2 method.

Establishment of the Experimental Runoff Plots

Nine runoff plots measuring 4.2 m x 14 m were established. The land with secondary vegetation, with a uniform slope gradient of 10%, was cleared and was prepared initially by disc plowing. Plots were demarcated on the upper and lateral sides of the plot using a 30 cm wide metal sheet embedded at 12 cm below the ground level. Metal sheet was fixed to the ground by clipping it with a round iron bar (10 mm).

A water runoff and soil erosion measurement system installed at the lower end of the slope consisted of a concrete sediment trap (10 cm in depth x 28 cm in width x 410 cm in length), slot divisors, plastic pail (60 L in capacity), and a runoff recorder. The slot divisors
were provided in the trap on the downstream side to avoid runoff overflow. The slot divisors also split the runoff water into equal portions and divided water flow into to the pail that was connected to the runoff recorder by a plastic hose. The runoff recorder consisted of a hand-made triangular tipping bucket with a mechanical counter. Additionally, an automated pulse sensor with a logger (UIZ-3639, UIZIN, Tokyo) was also installed on the side of the mechanical counter to check and confirm the mechanically measured values.

Water runoff was measured by summing up the water volume in the sediment trap with the recorded runoff volume after multiplication with the number of divisors in a given rainfall event. For soil erosion, the sediments in the sediment trap were collected, dried and weighed in a given rainfall event. A turbidity meter (compact-CLW, JFE ALEC Co., Hyogo, Japan) was installed in the pail to measure suspended sediments (SS) of runoff water passing the pail. Soil erosion was determined by summing up the weight of the sediments collected in the trap with the SS after multiplication with the number of divisors as well.

Experimental Design and Layout

Nine plots were arranged for the following 3 treatments: Tc, fallow + till (F+T), Tc, fallow + no-till (F+NT), and Tr. Pigeon pea + no-till (PP+NT) with three replications. During the fallow period after corn cropping, for PP+NT, pigeon pea was sown on February 27 at the interval of 23.3 cm between presumed corn rows and 10 cm between hills, giving 2 rows of pigeon pea between corn rows and a total of 12 rows of pigeon pea per plot. For F+T and F+NT, the land remained as natural fallow. Pigeon pea was grown for 3 months throughout the dry season and pruned at knee-high level just before corn sowing and pruned pigeon pea residue was left on the soil surface as mulch. Tillage in the F+T treatment was carried out using a small rotator. For F+NT, herbicide was applied to kill weeds before corn sowing. For the first cropping season, corn was sown on May 20 at a 70 cm x 20 cm distance with two seeds per hill. Fertilizer was supplied by spot application near the sowing pocket, following the 100 kg N–80 kg P2O5=60 kg K2O ha−1 recommendation for all the plots. Weeding during cropping, was carried out manually for the NT treatments, while for the T treatment, by manual shallow tillage and ridging. For the second cropping season, sowing was performed on October 26 as in the case of the first cropping. Corn residue was either incorporated (T treatment) or mulched on the soil surface (NT treatment). Continuous pruning was conducted during the entire growing period by cutting at knee-high level immediately after the first branching was observed.

Monitoring of Crop Agronomic Characteristics and Yield Survey

Crop performance and other agronomic characteristics such as plant height, greenness value (SPAD), girth size (5 cm above ground) and number of developed leaves were monitored in all the treatments on a monthly basis with 20 sampling plants per plot. SPAD chlorophyll meter (SPAD 502, Minolta, Japan) was used to measure the chlorophyll content or “greenness” of the crop and leaf N content.

Grain yield and biomass production were evaluated at each harvest in two ways: one by random sampling of 20 hills and the other by whole plot sampling. For the random sampling of 20 hills, the sampled hills were randomly but carefully selected in avoiding to miss the the surrounding hills, so that the effect of missing hills on the yield could be minimized.

Rainfall, Soil Temperature and Soil Water Measurement

Rainfall was measured using an automatic rain gauge (UIZ-DOT, UIZIN, Tokyo). Soil temperature for the three different treatments without replication (three plots) was monitored at 5 and 15 cm below the ground surface using thermocouples with a data logger (UIZ3633, UIZIN, Tokyo) without replication (three plots). Soil water content was also monitored only in the second cropping season using a Time Domain Reflectometer (TDR; CS-616, Campbell Scientific, Inc) horizontally installed at depths of 6, 15, 38, and 70 cm below the ground surface without replication (three plots). Data were collected at 10-min intervals for all the measurements to facilitate analysis among the above-mentioned parameters in all the treatments.

Statistical Analysis

All the data were subjected to analysis of variance based on SPSS program to determine statistically significant differences between the treatments, followed by Tukey’s B test at p < 0.05.

Results

Project Site Description and Soil Characteristics

The experimental site is under Type 3 Climate (Modified Coronas’ Classification) (PAGASA, 2007) characterized by the lack of a pronounced maximum rain period with a short dry season lasting for three
Table 1  Selected soil properties in experimental field, Baligatan, Ilagan, Isabela, Philippines

<table>
<thead>
<tr>
<th>Soil Depth</th>
<th>Texture</th>
<th>Solid phase</th>
<th>Easily avail. soil water</th>
<th>a)</th>
<th>pH (H₂O)</th>
<th>OM content</th>
<th>Total N</th>
<th>Available P</th>
<th>c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>Vol%</td>
<td>Vol%</td>
<td>cm/sec</td>
<td>(1:1)</td>
<td>(g kg⁻¹)</td>
<td>(g kg⁻¹)</td>
<td>(mg kg⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 16</td>
<td>Clay loam</td>
<td>65</td>
<td>28</td>
<td>1.4 x 10⁻⁵</td>
<td>5.6</td>
<td>20.6</td>
<td>0.7</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>16 - 31</td>
<td>Clay loam</td>
<td>67</td>
<td>24</td>
<td>9.3 x 10⁻⁵</td>
<td>5.9</td>
<td>12.0</td>
<td>0.4</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>31 - 59</td>
<td>Clay</td>
<td>66</td>
<td>30</td>
<td>2.8 x 10⁻⁵</td>
<td>6.4</td>
<td>8.1</td>
<td>0.4</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>59 - 95</td>
<td>Clay</td>
<td>63</td>
<td>32</td>
<td>6.6 x 10⁻⁵</td>
<td>7.7</td>
<td>5.5</td>
<td>0.2</td>
<td>ND</td>
<td></td>
</tr>
</tbody>
</table>

a) Easily available soil water indicates the difference between the volumetric water content at -6 kPa and at -98 kPa
b) SHC: Saturated hydraulic conductivity, c) OM : Organic matter content d) measured by Bray 2 methods
e) ND – Not Detected

(3) months. The dry period extends from January to April, while the wet period from May to December. The average rainfall was 1,755 mm/year (2004-2008) measured in the study field, while the average maximum and minimum temperatures were 31.2 °C and 18 °C, respectively (BSWM, 2000). Table 1 shows the typical properties of soil taken from pit at the study site at the start of the experiment. The soils of the area generally displayed a low in fertility with low organic matter (OM) content (2.1g kg⁻¹) in both surface soil and the subsoil (1.2g kg⁻¹). Available phosphorus (P) content was 0.3 mg kg⁻¹ with an acid soil reaction (pH 5.6 surface; and pH 5.9 subsoil). Soil texture ranged from clay loam to clay and the SHC was high at a surface horizon, while very low for the subsoil.

Agronomic Characteristics and Yield

As shown in Fig. 1a and 1b, the greenness (SPAD) value was slightly higher in the PP+NT than in the other two treatments in both cropings, although the values were not statistically significant. In addition, the soil organic matter content in the PP + NT treatment increased since a pigeon cover crop had been introduced, as shown in Fig. 2. However, crop characteristics such as plant height, number of developed leaves and girth size were not different from each other (data not shown).

Grain yield based on 20-hill sampling is shown in Fig. 3a. There was no statistically significant difference among the treatments in the first cropping. However, the order of yield was PP + NT > F + NT > F + T. The yield in the PP+NT treatment was higher by a 1 ton, compared with the F+T treatment and by about 0.4 ton for the F+NT treatment during the first cropping. The second cropping tended to show a similar trend in which the PP+NT treatment led to the highest grain yield of 4.9 ton ha⁻¹, compared with 4.2 and 3.9 ton ha⁻¹ for F+NT and F+T plots, respectively. General improvement in yield observed in all the treatments in the second cropping compared with the first one was possibly due

Fig. 1  SPAD value on different days after planting during the first cropping (1a) and the second cropping (1b). Vertical bar shows standard variation. F+T; fallow + Tillage, F+NT; fallow + No-tillage, PP+NT; Pigeon pea + No-tillage. SPAD value with the same letter: not statistically different at p = 0.05.

Fig. 2 Changes in soil organic matter content after harvest between treatments for two cropping seasons of corn. Sampling time: Before planting (Feb 2008); After first harvest (Sep 2008); After second harvest (Feb 2009). Vertical bar indicates standard deviation. Sampling time with the same letter are not statistically different at p = 0.05.
to the higher availability of soil water at the start of the cropping and higher photosynthetic activity in the later part of the season.

Regarding the yield of the whole plot, as shown in Fig. 3b, the value for the PP+NT treatment were not any significantly different in the first cropping season because of a higher rate of missing hills in the PP+NT treatment (39%), compared with the F+NT (15%) and F+T(26%) treatments. Lithourgidis et al. (2005) reported that the presence of missing hills is a problem in no-till agriculture. However, the yield for the PP+NT treatment in the second cropping was highest with a significant difference, compared with the F+T treatment, but not for the F+NT treatment. The lower rate of missing hills (F+T: 1%, F+NT: 9%, PP+NT: 22%) compared with that for the first cropping season in the PP+NT treatment was probably due to more favorable soil moisture condition at sowing time for all the treatments.

Soil Water and Temperature Regime during the Cropping

Soil water content at various depths

Fig. 4 compares the changes in the soil water content at various depths during the period of October 2008 to February 2009 (Second Cropping). As shown in Fig. 4a, the soil water content at the upper 6 and 15 cm depths was easily affected by rainfall events, as indicated by the combined abrupt rise in the soil water content in response to rainfall and sudden decline. However, during a continuous high rainfall event associated with a typhoon in November, the soil water content was not appreciably affected, probably due to the high soil water content, compared with the soil water content of 0.49 m3 m-3 at -6 kPa and 0.23 m3 m-3 at -98 kPa on average for the two top horizons. At a 70 cm depth, a stable and higher soil water content was observed during the measurement period, indicating that water was not depleted by absorption by roots. However, the soil water content in the PP+NT treatment decreased during the maturation stage (end of January to end of February), and later it increased rapidly when a severe rainfall event occurred (Feb. 17-18; 96.5 mm of rainfall). Soil water content in the other treatments, F+NT and F+T, did not respond significantly to this event. Greener leaves even at lower position in the PP+NT treatment were observed, compared with the other treatments where lower leaves dried up, suggesting continuous photosynthesis and water uptake persisted until the end of maturation.

Soil temperature

Figure 5 shows the important effects of pigeon pea residue mulch on the soil temperature, particularly in the upper soil layers (i.e. 5 cm depth) for the three treatments during the second cropping in 2008-2009. Maximum soil temperature for the PP+NT treatment was relatively lower than that for the F+NT and F+T treatments during the initial growing period of the first cropping. However, during the latter part of the growing period until the second cropping, approximately, the same maximum soil temperature level was observed in all the treatments. Similar trend was observed at a 15 cm depth (data not shown).

Water Runoff and Soil Erosion

Fig. 6 shows the measured runoff values during the first and second cropping seasons in 2008-2009. Water runoff was 24.2 mm for the F+T treatment, 15.7 mm for the F+NT treatment, 11.6 mm for the P+NT treatment, respectively. The second cropping season corresponded to the period when rainfall in the study area was maximum due to typhoon (i.e. November-January), during which some monitoring equipment was damaged and only one series of runoff and soil erosion value was available.

During the first cropping period, water runoff was
Fig. 4 Curves of soil water content at various depths measured during the period of October 2008 to February 2009 (Second Cropping). (4a) at 6 cm depth, (4b) at 15 cm depth, (4c) at 38 cm depth, (4d) at 70 cm depth. The circle in (4d) shows the decrease of the soil water content and subsequent rise during the rain event for PP+NT treatment.

Fig. 5 Curves of maximum soil temperature measured at 5 cm depth during the periods of Jun- Sep 2008 (First Cropping; 5a) and Oct 2008– Feb 2009 (Second Cropping; 5b).

Fig. 6 Cumulative water runoff during cropping; (Rainfall for 1st cropping: 655 mm, 2nd cropping: 955.5 mm)

Fig. 7 Cumulative soil erosion during cropping; (rainfall for 1st cropping: 655 mm, 2nd cropping: 955.5 mm)
low. However, the runoff for the PP+NT treatment was lowest, probably due to the dense pigeon pea residue mulch. During the second cropping period, a higher runoff was recorded for all the treatments. Among the treatments, however, PP+NT showed the lowest runoff, followed by F+T, and F+NT. During the second cropping period, the pigeon pea residue mulch was still present and residue mulch was continuously added, while the soil was left bare for the F+NT and F+T treatments. Under the bare condition, NT treatment seemed to be more vulnerable to a higher water runoff.

Fig. 7 shows soil erosion for the two cropping seasons. Overall, the measured soil erosion in this experiment ranged from 400 to 1200 kg ha\(^{-1}\) for both cropping seasons (Jun 2008 – Jan 2009). The bulk of the soil erosion in this experiment corresponded to suspended sediments (376-820 kg ha\(^{-1}\)). The low soil erosion can be attributed to the gentle slope (10%) in the experimental plots. The highest soil erosion was recorded during the second cropping period when heavy rainfall occurred due to a typhoon that hit the area at the end of November (Nov. 22\(^{nd}\)).

During the first cropping period, soil erosion for F+T occurred only at the initial stage, while no soil erosion was recorded at the later stage. The bare and tilled soil is presumably more vulnerable to soil erosion than untilled soil together with either pigeon pea residue or weed mulch. At the later stage, soil erosion was not recorded probably due to the dense vegetation of corn. During the second cropping period, soil erosion occurred also at the initial stage of the growing period in the order of F+T > F+NT > PP+NT. In contrast to water runoff, the NT treatment appeared to be a more important factor for soil erosion.

**Discussion**

*Effects of Pigeon Pea Cover Crops on Yield*

The order of the 20 hill-based yield was PP+NT > F+NT > F+T for both seasons, although there were not significant differences. Previous studies showed the presence of a strong correlation between the SPAD measurements and the leaf nitrogen (N) content (e.g., Gholizadeh *et al.*, 2009; Kowalczyk-Jusko and Kościk, 2002). Although the addition of pigeon pea leaves as mulch must have provided N to the soil and to the corn plant, the effect of pigeon pea on SPAD values was not statistically significant. The effect of pigeon pea residue mulch was also observed on the level of soil organic matter and TN of the surface soil (Fig. 1). While cover crops promoted the increase in the organic matter content, the degree of their contribution depended on many factors such as high temperature, high rainfall and whether the crops were removed from the field, left on the surface or incorporated into the soil (Peet, 1995).

Difference in yield between the F+NT and PP+NT treatments was negligible. Surface mulch with weeds after herbicide spraying was also effective in terms of soil erosion prevention (Fig. 7). However, direct contribution of F+NT to the yield has not been demonstrated in the present study.

Comparison of differences in yield among the treatments between 20 hill- and whole plot-based yield, clearly indicated the importance of the rate of missing hills for the yield. For the second cropping, since the missing hill rate became relatively low among the treatments, statistically significant yield increase was obtained on the whole plot basis (F+T vs PP+NT). In the present experiment, sowing was performed by dibbling manually, and the depth of sowing was sometimes insufficient due to the hard soil surface and inappropriate soil cover under lower soil moisture condition in the first cropping season, resulting in a higher rate of missing hills at PP+NT treatment. This fact suggests that appropriate seeding equipment to reduce the rate of missing hills under “no-till” condition is necessary.

*Effects of Pigeon Pea Cover Crop on Soil Moisture and Temperature Regime*

According to Sarrantonio (2007), cover crops could act as “living plows” that penetrate and break-up compacted layers through their roots. They increase the soil ability to absorb and hold soil water, which minimizes surface runoff. These effects could be based on the behavior of the soil water movement in the soil profile, as shown in Fig. 4, in which the soil water curve of PP+NT treatment during maturation stage decreased during the lull period even in the deeper horizon. This suggests the presence of a higher absorption by plant. Also, refilling of water afterwards suggested the existence of a higher infiltration despite the very low SHC (Table 1).

Pigeon pea as residue mulch also enabled to control the soil temperature, particularly during the day time, by protecting the soil surface against direct solar radiation, particularly at the initial stage during the first cropping of corn (Fig. 5a). This is important because decrease in the soil temperature enables to prevent excessive respiration and photosynthesis loss. Decrease of the soil temperature is also expected to reduce soil organic matter decomposition. However, the standing pigeon pea density decreased by shading by the main
crop in the later part of the first cropping and during the second cropping, which then reduced its role in the control of the surface soil temperature (Fig. 5b), along with the decrease in the initial residue mulch biomass due to decomposition. Therefore, appropriate cover crop management through dense planting and introduction of more shade-tolerant legumes is also important. Nevertheless, surface residues (i.e. pigeon pea cuttings) may also reflect solar radiation and insulate the soil surface (Shinners et al., 1993).

Pigeon Pea as Cover Crop for Soil Conservation in Sloping Lands

The impacts of each treatment on soil and water conservation can be evaluated through surface runoff and soil erosion analyses. While tillage could provide soil conditions conducive to plant growth through proper aeration and maintenance of the soil infiltration capacity, tillage without consideration of soil, weather and crop conditions and topography may result in soil degradation due to the loss of structure and erosion. Results in Fig. 7 indicate that no-tillage treatments can significantly reduce soil erosion in the magnitude of about 1000 kg ha⁻¹. These results can be attributed to the lack of disturbance of the soil mass and maintenance of the soil cover (crop residues and standing biomass), resulting in lower dispersion and consequently lower soil movement. Baker and Laflen (1983) reported that even in soils with a high erosion potential, soil erosion is far below the tolerable limit under the no-tillage system. In the present study, soil erosion in the PP+NT treatment is also decreased by more than 200 kg ha⁻¹, compared with the F+NT treatment, suggesting the beneficial effect of the cover crop. Pigeon pea residue by pruning put on the soil surface could have acted as hedges that minimize the movement of the soil particles and enable to hold the soil mass. In addition, pigeon pea protects that ground from rainfall and reduces soil erosion. Steiner (2002) reported the benefits of ground cover in decreasing soil erosion. Hussain et al. (1998) demonstrated that, a 50% reduction in soil erosion could be attained by using a 70% ground cover.

In essence, the impacts of soil conservation approaches can be optimized through a combination of no-tillage and cover crop residue mulch, as revealed in the present experiment.

Conclusion

Based on the results the following can be concluded:

1. Appropriate management of pigeon pea as cover crop and subsequent residue mulch could contribute to the improvement of the soil organic matter content. While in soils under “no-till” condition the soil organic matter content can increase by 0.1 to 0.20 percent per year (Crovetto, 1999), combination of this technology with pigeon pea cover cropping is a suitable soil conservation management practice.

2. Pigeon pea cover crop and subsequent residue mulch could reduce the maximum soil temperature, by affecting many factors such as evaporation, decomposition of organic matter under the subtropical hot climatic condition. However, the important role of pigeon pea cover crop decreases when the crop is overshadowed by the main crop and becomes sparse;

3. Pigeon pea and no-till combination as a conservation tillage practice can be applied for sustainable corn production due to the reduction of soil erosion and enhancement of crop yield and

4. Future studies should focus on the design of appropriate seeding equipment to reduce the rate of missing hills under “no-till” condition.

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