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DECOMPOSITION RATES OF INTERCROPPED GREEN MANURE CROPS IN OAXACA, MEXICO

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Abstract: In the Central Valleys of Oaxaca, México, crop production is seriously limited by soil moisture and fertility, as well as by land scarcity. To try to alleviate these constraints, an experiment to evaluate the feasibility of producing green manure crops intercropped with maize (*Zea mays*), residue decomposition rates and nitrogen content at full bloom was conducted. The mung beans (*Vigna radiata*) and dolichos beans (*Dolichus lablab*), planted as single crops, out yielded widely the other species evaluated, but decreased significantly their dry matter production when intercropped with maize, particularly mung beans. Maize production was also affected by the intercrops, especially crop grain yields when grew associated with crotalaria (*Crotalaria juncea*). On average, biomass production of intercropped legumes decreased 31.3 %, with extreme values of 22.1 % for crotalaria and of 37.4 % for mung beans. Using the methodology of burying residues contained in mesh bags, it was found that mung and dolichos beans showed the highest decomposition rates (8.8 and 9.1 g ha^{-1} per day, respectively), while crotalaria and common beans reached values of 4.1 and 5.7 g ha^{-1} per day, respectively. Decomposition rates were significantly related to soil temperature and water content, as well as to C/N ratios of the residues. Given its characteristics of high drought tolerance and rate of height increase when intercropped, crotalaria is a species suitable for intercropping with maize in more marginal areas. Because of its growth habit and long life cycle, which minimizes competence with maize during its critical stages, dolichos bean has a good potential to grow well in association with maize in deep soils under rain-fed conditions.
Key Words: Crotalaria, Dolichus, Vigna, Phaseolus, Poor soils, Peasant agriculture

1. INTRODUCTION

In the region of the Central Valleys of Oaxaca there are serious limitations for the production of maize, the staple food crop of most Mexicans. Among the main problems are mid summer drought and low soil fertility are included (Ruiz and Silva, 1999).

A possible alternative to solve the problems of low fertility and variability of crop production is the association of maize with legumes. The maize-bean intercrop, where the beans are an early variety, is more likely to produce, given the greater precocity of beans (Herrera and Ruiz 1994, Ruiz and Loaeza, 2004). The problems of low soil nitrogen and variable rainfall, can be alleviated with the association of maize with drought-tolerant legumes (Graham and Ruiz, 1996).

Sangakkara *et al*. (2004) found that the addition of green manure for three years was reflected in an improvement of the physical properties of soils, as well as increased amounts of available N, P and K. Incorporation of Crotalaria, with higher nitrogen content, promoted plant growth, while Tithonia favored the development of the root system of maize. In a previous study (Ruiz and Loaeza, 2003), we investigated the possibility of producing green manure crops in association with maize under rainfed conditions in the Central Valleys of Oaxaca, but the humidity conditions could be limiting for decomposition of the plant material, as well as for nutrient mineralization. In Tabasco, Mexico, it was found that temperature and high humidity favored the decomposition of Mucuna pruriens residues, but under excessive moisture decomposition rates decreased by about 50% (Jerome *et al*., 2002). Other factors affecting the rate of decomposition are the C / N ratio, which is determined by the nitrogen content of crop residues and soil. Ellis *et al*. (2003) reported that the amount of N mineralized was higher in alfalfa residues than in grass residues, given the lower C/N ratio in the legume. In this area, nitrogen (N) is the major constraint to maize production, therefore the N derived from symbiotic fixation is an important component of soil fertility and is required to know more accurately the contribution of symbiotic N to soil reserves. The precise quantification of total nitrogen of the plant is difficult due to the difficulty to include the rootlets and rhizosphere fractions of root systems (Kuskopf *et al*., 2003). The nitrogen content in the roots, which is proportional to its dry weight varies between 28 and 52% of total N accumulated per plant (Rochester *et al*., 1998, Khan *et al*., 2002).

The proportion of nitrogen in the root and aerial parts is differentially affected by water stress according to the species of legume. Ludlow (1989) reported that the decrease of soil moisture reduced the amount of N in both root and aerial parts of the two legumes. However, mung bean maintained a nearly constant proportion (35 to 40%) of N in the roots, while the peanut increased its value from 24 to 44%.

This study was aimed to assess the rates of decomposition of crops that can serve as a green manure, planted in monoculture and also associated with maize under rain-fed conditions, as well as the potential contribution of organic matter from aboveground and belowground structures.

2. MATERIAL AND METHODS

The experiment was planted June 15, 2001 in Santa Cruz Xoxocotlan, Oax., Mexico in a deep sandy loam soil of fluvial origin, but low in organic matter (0.70%) and with medium levels of phosphorus and potassium (9.40 mg kg^{-1} and 1.72.cmol (+) kg^{-1}, respectively).

Santa Cruz Xoxocotlan is located at 17 º 03 'N and 96 º 43' W, at an altitude of 1552 m. It has an average

annual temperature of 21.5 º C, with average monthly maximum of 36.4 º C in May and minimum of 5.8 º C in January. Average annual rainfall is 660 mm, concentrated in the months of June to September; in this period, the monthly maximum temperatures range between 31 and 33 º C while the monthly minimum temperatures range between 11 and 13 ºC.

The experimental treatments consisted of four legumes planted in monoculture and associated with maize (*Zea mays*) var. "Criollo Bolita". The legumes were common bean (*Phaseolus vulgaris*) var. thin black, mung bean (*Vigna radiata*) var. Texas, Dolichos bean (*Lablab purpureous*) var. Brown and Crotalaria (*Crotalaria juncea*). The maize planting density was maintained at 40 000 plants ha^{-1}, while legumes were seeded at a density of 66% of the planting rates used in their monocultures.

During the growing season data on crop growth, rainfall and temperature were collected. Plant heights and development were measured in 10 plants per plot every 15 days using the Fehr *et al.* (1971) system for legumes and Ritchie *et al.* (1992) for corn. When legumes reached full bloom (R2) we estimated dry matter production at the roots and shoots from a sample of 10 plants per treatment and repetition. The plants were pulled out from the soil, which had a good moisture content, the root and shoots were separated and placed to dry for 48 hours in an oven at 70 ºC.

The proportion of dry matter present in the roots (PPR) was estimated using the following formula:
PPR = (root weight / (root weight + weight aerial part)) x 100.

To estimate the rates of decomposition, we buried 15x20 cm mesh bags in two replications per treatment, at a depth of 15 cm. Each bag contained 10 g of fresh material from the aerial part of Crotalaria, Dolichos bean, mung and common bean. This amount was equivalent to 986.6, 916.5, 1086.4 and 1016.3 kg ha^{-1} of dry matter according to the moisture present in each species. The determination of the N percentage of crop residues was by the Kjeldahl method (AOAC, 1999).

The bags were removed at three, six and nine weeks after placement, and thus obtained 2 remaining weight values, for a total of 6 per species. During this period were quantified minimum and maximum temperatures of soil (7-8 and 14-15 h) to 15 cm deep (glass thermometer mod Taylor brand. 6332), and its moisture content by gravimetric method.

Also were generated linear models (SAS, 2002) to relate the decay rates of residues with average soil temperature and moisture.

3. RESULTS AND DISCUSSION

3.1. Plant Height and Dry Matter Production

Under conditions of monoculture, maize was the dominant crop, followed by crotalaria. The latter one showed greater height under association than in monoculture at all dates. The common and mung beans showed very low rates, but were not significantly affected by competition with corn until 48 days after planting (dap). At 61 dap, the height of the latter crop was significantly lower in association, while the Crotalaria and dolichos beans in policulture tended to exceed the height observed in monoculture.

Competition between crops under policulture starts from the time of emergency. Effects of high competition between tall corn varieties and legumes have been reported. Parra (1989) found that hybrid corn was not suitable to be associated with common bean or mung bean given its height. In this study, mung beans were more affected than the common bean when associated with maize.

Jeranyama *et al*. (2000) found that two green manure species associated with maize responded differently according to their growth habit. *Vigna ungiculata* showed less growth than *Crotalaria juncea* because the latter has an upright growth habit which allows crotalaria to intercept more solar radiation.

Regarding the time of coexistence between crops, corn stopped growing at 65 dap, while dolichos beans continued to grow up to 130 dap. Thus, the critical stages occur in very different dates, and a high interspecific competition was not observed.

In another study, associations of jack beans-maize and jack beans-sorghum were compared and found that the intensity of interspecific competition was greater in the first association, as the corn plants were higher than those of sorghum, as well as the coexistence time (Contreras *et al*., 1989).

In this study, Dolichos and mung beans grown in monoculture surpassed all other species tested, but also decreased significantly their productivity when associated with corn, especially mung beans. On average, the biomass yield of associated legumes decreased 31.3%, with extreme values of 22.1% to 37.4% for crotalaria and common beans, respectively. These results are similar to those reported by Ruiz and Loaeza (2003), who found average declines of 28.5% in soybeans and chickpeas when they were associated with maize in the same region. However, for the common bean *Phaseolus vulgaris* reductions of up to 45% have been observed when associated with maize (Clark and Francis, 1985).

Apparently the root / shoot ratio (R/S) of beans is highly influenced by soil fertility. Thus, Bernal *et al*. (2007) reported values of 33 % of roots in cv. C60 in a soil fertilized with diammonium phosphate, whereas without fertilization there were values close to 50 %. Also Avilán and Louis (1976) reported that the proportion of roots in beans cv "Carioca" varied between 18.0 and 25.2 %, the highest value was found in a very low soil P.

In another study, dry matter yields for Crotalaria were from 0.9 to 2.9 t ha^{-1} (Jeranyama *et al*., 2000), while for eight varieties of beans planted in monoculture at high densities values from 0.7 to 1.8 ton ha^{-1} were obtained at full bloom (Araujo *et al*., 2000).

For dolichos beans, the production of the aerial part, evaluated at 19 weeks after planting, was 1.8 to

2.0 ton ha^{-1} of dry matter (Carsky *et al*., 1999). The yield of green manure of mung beans has been estimated between 1.1 (Thonnissen *et al*., 2000) and 2.3 ton ha-1 dry matter (Leyva *et al*., 2003).

Table 1 shows the values of R/S for different crops. The maximum values of R/S were observed for Crotalaria both in monoculture and in association. These values seem low, especially when compared to figures reported by Stoffella (1979), who estimated that the amount of dry matter remaining in the roots of common beans can be up to 58%. In an evaluation of 13 species of leguminous cover crops, which included the Dolichos bean, it was found that root weight represented about 1 / 3 of the total weight of the plant (Tian and Kang, 1998).

Crotalaria and mung beans showed the highest values of R/S both in monoculture (25.3 and 21.8%) and in association (22.7 and 18.6%); also they were the least affected in terms of R/S when associated with corn (10.2 and 14.7 %). Islam *et al*. (2007) reported variations from 15.7 to 21.2% in the R/S of 530 genotypes of mungbean. Rajendira and Ramanujam (2004) reported values of dry weight of roots and shoots of 4.9 and 24.9 g / plant, respectively, for the cultivation of mung beans var KM-2, resulting in a R/S = 19.6%.

Maize yields were also affected, especially grain production, when associated with crotalaria. This is a legume with a high growth rate, which allowed it to compete effectively with corn for light in the vegetative growth stage.

3.2. Decomposition Rates and Nitrogen Supply

Maximum decomposition rates were observed in mung beans and Dolichos (8.8 and 9.1 g ha^{-1} per day, respectively) at the maximum values temperature and moisture contents experienced (24.5 º C and 12.6 %). This means that in four weeks with adequate conditions of humidity and temperature, around 250 kg ha^{-1} would decompose when these green manures are incorporated into the soil, which was equivalent to 23% of mungbean residues and to 35% of dolichos bean residues. These values of decomposition are lower than those reported by Njunie *et al*. (2004), whom, in a more humid environment, found that the percentage of residues remaining in dolichos beans was 54, 35, and 25% after 2, 4 and 8 weeks of incorporation. In another study, Dolichos beans with a C/N ratio of 11:1, lost 63% of their initial weight after four weeks (Ibewiro *et al*., 2000).

The crotalaria and beans showed the lowest decay rates, reaching 4.1.y 5.7 g / day, respectively, under the maximum conditions of temperature and humidity shown above. We know that these rates were also conditioned by the C/N ratio, in addition to the soil nitrogen content (Ryan *et al*., 2003). Table 5 shows that these two species had high values of C/N.

Abreau (1996), found that the rate of decomposition of crop residues evaluated during the rainy season, varied with the crop species, noting a slower decomposition in *Crotalaria juncea*, followed by *Cajanus cajan, Phaseolus lunatus* and *Canavalia ensiformis*. After 32 days, *C . juncea* had lost 26.8% of its initial dry weight, whereas *C. ensiformis* had lost 69.3 %. The C/N ratio was higher in *C. juncea*. Table 2 shows the percentages of nitrogen for the four species in both above and below ground plant parts, as well as the C/N ratios. Dolichos and mung beans showed higher contents and contributed the largest total amount (35-62 kg ha^{-1}).

Dolichos and mung beans can contribute up to 80-106 kg ha $^{-1}$ N (Cherr *et al*. 2006; Shah *et al*. 2004), while crotalaria is characterized by its high fiber content in the stem and a low leaves/stem ratios; while it's C/N ratio is close to 40 (Yano *et al*., 1994;), its N supply capacity was estimated at 53 kg ha^{-1} (Jeranyama *et al*. 2000). Beans are characterized by their low capacity for symbiotic N fixation, which coupled with its low biomass production, resulted in a contribution of only 19-28 kg N ha-1 (Araujo *et al*., 2000; Ojiem *et. al.*, 2007).

Table 1. Dry matter yields and root/shoot ratios of mono and intercropped green manure species

Crop or policulture	Residues (kg ha^{-1})	Roots (kg ha^{-1})	Root/shoot ratio (%)
Common beans (CB)	1219 c †	248 bc †	16.9 c †
Mung beans	1955 b	546 a	21.8 b
Dolichos beans	2865 a	666 a	18.8 c
Crotalaria	1731 b	587 a	25.3 a
Maize-CB	763 d	111 c	12.7 d
M.- mung beans	1290 c	296 b	18.6 c
M.- dolichos beans	1951 b	324 b	14.2 d
M.-crotalaria	1347 c	396 b	22.7 ab

† Values with the same letter are not statically different according to Duncan (P< 0.05) test

Table 2. Nitrogen content, C/N ratio and total N content of four species of green manure crops associated with maize

Crop under policulture	N content (%)	C/N ratio	Total N content (kg ha^{-1})
Common beans	2.32	18.75 b	17.70 c †
Crotalaria	1.94	22.42 a	34.21 b
Mungo beans	2.76	15.76 c	35.60 b
Dolichos beans	3.21	13.55 c	62.63 a

† Values with the same letter are not statically different according to Duncan (P< 0.05) test

4. CONCLUSION

The crotalaria considerable height growth rates, especially when planted in association. Given its high drought tolerance, is a species with high potential for cultivation as green manure in association with maize in areas with thin soils and low or ill-distributed rainfall.

Another promising species for policulture is the dolichos bean, since it's growth habit and life cycle avoid competition for resources in the critical stages of corn, therefore it is recommended in association with corn for deep soils in rain-fed areas.

Decomposition rates were highly conditioned by air temperatures and soil moisture, as well as the C /N of the crop residues.

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