African Crop Science Conference Proceedings, Vol. 6. 42-46
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ISSN 1023-070X $ 4.00
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Light availability within an innovative maize-legume intercropping system in Western Kenya

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Abstract An experiment was conducted in western Kenya to characterize the penetration of solar radiation into the canopy of different maize-bean intercropping systems. The conventional system consisted of alternating 37.5 cm rows of maize and beans. A staggered system contained the same plant population but was planted as paired maize and bean rows. Rows were oriented either east-west or north-south. The experiment was arranged as a 2 x 2 factorial in a Completely Randomized design. All treatments received 31 kg N and 20 kg P ha^{-1} as mineral fertilizer. Solar radiation was measured at maize tasseling at positions above the maize canopy, above the bean understorey and above the soil. Crops were harvested at maturity and yield compared to light penetration patters. Maize yields were affected by neither row arrangement nor orientation and averaged 4.9 t ha^{-1}. Bean yields were significantly greater in the staggered row arrangement (+320 kg ha^{-1}, $p = 0.021$) but not row direction. Light penetration to the beans was affected by row arrangement ($p<0.001$) and demonstrated an interaction between row arrangement and time of day ($p<0.001$). Staggering the row arrangement resulted in 20% more light to the understorey legume, an increase of 11500 LUX when averaged throughout the day. The net returns increased by KSh 5356 ha^{-1} (US $69) in the MBILI compared to conventional intercropping. These findings suggest that staggered intercrop arrangements offer advantage over the conventional one and that part of that improvement is related to light penetration to understorey legumes.

Key Words: Crop management, light, orientation

Introduction

Most smallhold farmers in western Kenya practice maize-bean intercropping as their main farm enterprise because it provides both food for the household and market opportunities (Woomer *et al*., 1997). Improvements to the conventional intercropping system, with alternating 37.5 cm rows of maize and beans, is somewhat problematic, as the additional costs of inputs often exceeds the value of the increased yield. This dilemma results from a complex combination of low commodity prices (Nyangito *et al*., 1997), low soil fertility (Sanchez *et al*., 1997), expensive fertilizers (Mwaura & Woomer, 1999) and uncontrolled crop pests and diseases (Abate and Ampofo, 1996) that have forced many farmers to resignedly accept chronically low yields. An alternative maize-legume intercrop rotation was designed through three years of on-farm trials that sought agronomic solutions to difficulties in conventional intercropping.

The modified intercropping system, designated MBILI (*kiswahili* for "two"), staggers crop arrangement in two 50 cm maize rows separated by a one meter strip reserved for the legume intercrop (Tungani *et al*., 2002). In this way the same maize populations are maintained and grown with a wider selection of higher value pulses such as groundnuts (*Arachis hypogea*), green gram (*Vigna radiata*) and soyabean (*Glycine max*), that in turn allows for greater returns to modest investment in fertilizer inputs. Several years of on-farm trials suggest that MBILI results in an increase of 422 kg maize, 443 kg pulses and KSh 23300 net return (about US $300) per hectare over conventional intercropping. Much of MBILI's advantage presumably rests in reduced crop competition but no detailed information on light penetration through the intercrop canopy was available. This study therefore evaluated the light penetration in the bean maize intercrop arrangement.

Materials and Methods

A two x two factorial experiment in Bungoma, Kenya in a Completely Randomized design that examined row arrangement (MBILI vs. conventional spacing) and row orientation (N-S vs. E-W) in a maize (*Zea mays* cv. H513) and bean (*Phaseolus vulgaris* cv. Rose Coco) intercrop. The area is densely populated by smallholders managing an average 0.95 ha of Ferralsols and Acrisols formed on acid igneous rock (Sombroek *et al*., 1980) receiving approximately 1800 mm annual precipitation. Rows were arranged as alternate 37.5 cm maize and beans (conventional) or staggered 50 cm paired maize rows separated by two 33 cm bean rows (MBILI). In-row spacing of maize and beans were 30 cm and 15 cm, respectively, resulting in populations of 44,444 maize and 88,888 beans ha^{-1} in both intercropping systems. The individual plots were fertilized at the rate of two 50 kg bags of DAP ha^{-1} (18 kg N and 20 kg P). CAN side dressing (13 N kg ha^{-1}) was spot placed adjacent to maize at the bootleaf stage.

At early maize tasseling, light measurements were taken above maize, above beans and above the soil at randomly selected positions at 0.5 hour intervals using a hand-held light meter. Beans were subsequently harvested by uprooting the plants, allowing them to dry, shattering the pods and collecting and cleaning seeds. Maize was later harvested by recovering the ears, allowing them to dry, husking and shelling the cobs. Bean seeds and maize kernels were allowed to air-dry and then weighed on a spring balance.

Two data sets were compiled, one that contained the light measurements in the four treatments throughout the day and another that contained data on crop yield, crop value and net returns. Because light measurements were not simultaneous within different treatments and replicates, the light measurements were grouped into five time categories (early morning, mid-morning, mid-day, mid-afternoon and late afternoon). Light interception by beans was calculated as the difference above and below its canopy. Analysis of Variance was subsequently performed on the three light positions and bean light interception using the model statement *light intensity = constant + arrangement + orientation + (arrangement x orientation) + time + (arrangement x time) + (orientation x time) + (arrangement x orientation x time)*. Similar analysis was performed for crop yield and economic return data but time and its interactions were not included within the model statement. When main effects of interactions were significant, mean separation was performed by calculation of the Least Significant Difference ($LSD_{0.05}$). Light measurements were also represented as a line graph where above maize measurements were pooled and the above bean measurements expressed on a treatment basis.

Results and Discussion

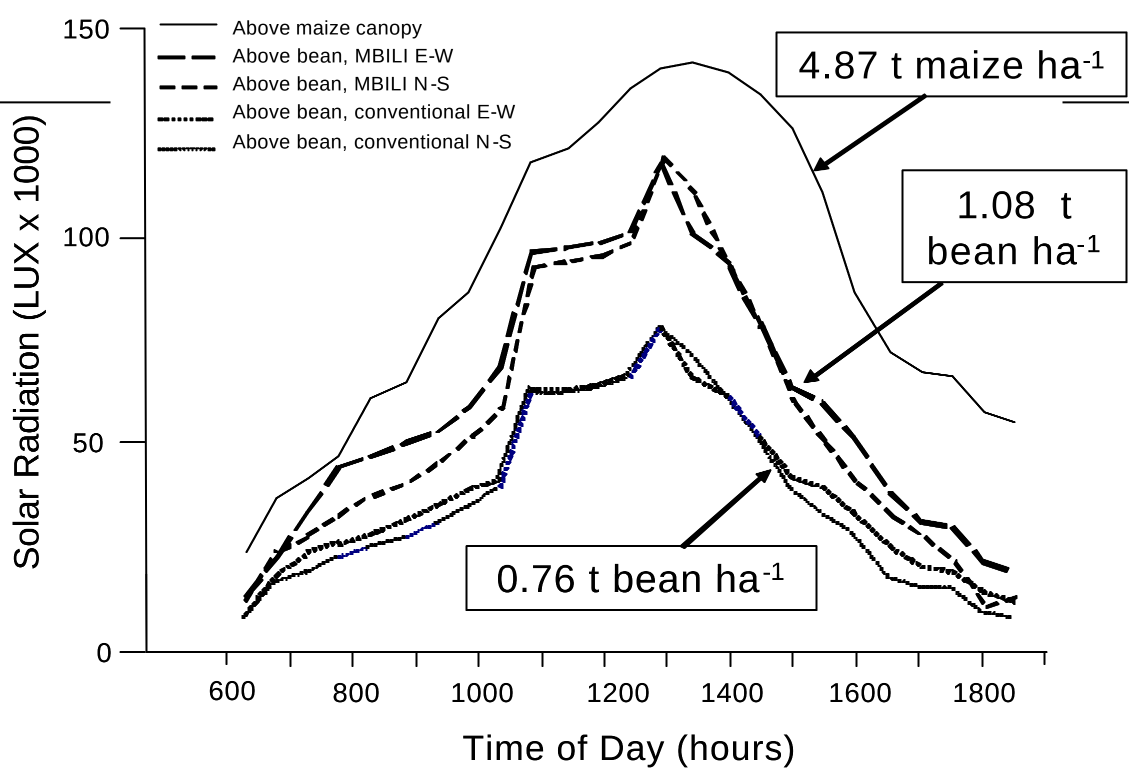
The summarized results from ANOVA of the light data are presented in Table 1. A significant effect of time was noted for all measurements, a difference as obvious as night and day. No significant effects were observed in the light measurements taken above the maize canopy except for time of day, a result to be expected as all treatments reside beneath the same sun and variation in this measurement is governed by random scattered clouds and haze. Row arrangement and the arrangement x time of day interaction were significant for light measurements taken above the bean canopy. Similarly, light interception by bean was regulated by row arrangement and orientation and the orientation x time interaction. These findings suggest that light availability to the legume understory is independently managed through the staggered row arrangement of MBILI and the direction of its rows and that these two factors interact with the direction of the sun throughout the day.

The light measurements of the three canopy positions throughout the day are presented in Table 2. Note that the mean values are expressed as LUX x 10^2 and are accompanied by the SEM in parenthesis. Staggering the row arrangement resulted in 20% more light to the understorey legume, an increase of 11500 LUX when averaged throughout the day. Optimal light occurred mid-day but its timing is shifted slightly toward the afternoon because Bungoma falls somewhat to the west within the East African Time Zone (GMT +3) and is quite close to the equator. The greatest light penetration beyond the maize canopy occurs in the MBILI system with east-west row direction, a difference that is more pronounced during the earlier and latter part of the day.

The effects of row arrangement and orientation on crop yield and economic returns are presented in Table 3. No significant treatment effects on maize were noted and the overall yield was 4.9t ha^{-1}. Row arrangement significantly influenced bean yield and value (p=0.02) and total and net returns (p=0.04). The effects of row orientation on bean yield and returns were not significant (data not presented). An increase bean yield of 320 kg ha^{-1} was attributed to the MBILI spacing and was most pronounced with an east-west row orientation (p=0.09). Staggering the maize rows according to the MBILI recommendation resulted in an overall economic gain of KSh 5356 ha^{-1} (US $69).

The light and yield data are combined and presented in an alternative manner in Figure 1. Note that the radiation is expressed as LUX x 10^3 and that incoming solar radiation are pooled into a single trend. At mid-day in the MBILI system, an additional 402,000 LUX penetrates to the bean canopy, although not all of this additional radiation is intercepted by the crop (Table 2). The advantages of morning and afternoon light penetration resulting from an east-west row orientation, regardless of row arrangement, are also apparent in Figure 1, although these differences were not significant (Table 1)

The findings of this study have immediate relevance to smallhold farmers in the process of examining and adopting the MBILI maize-legume intercrop rotation (Tungani *et al*., 2002). Firstly, MBILI effects are obtained regardless of row orientation which allows them the option to run their rows along the soil contour as a soil conservation measure (Lal, 1990, Tenywa et al., 1999). On the other hand, benefits accrued from orienting rows in an east-west direction are much smaller, this approach should not be ignored in more-or-less level fields. The benefits from MBILI result from better understorey legume performance and maize yield is not adversely affected from altering (and alternating) row spacing. The latter observation complies with the principle of maize elasticity (citation) where yield and its components adjust to competition effects and establish a "yield plateau" over a wide range of plant populations.


150
100
50
0
Solar Radiation (LUX x 1000)
Above maize canopy
Above bean, MBILI E-W
Above bean, MBILI N-S
Above bean, conventional E-W
Above bean, conventional N-S
4.87 t maize ha-1
1.08 t bean ha-1
0.76 t bean ha-1
600
800
1000
1200
1400
1600
1800
Time of Day (hours)

The study has some limitations, principally related to reliance upon a mobile, handheld light meter rather than multiple, and fixed position light sensors. Nonetheless, our findings have demonstrated the advantages of light penetration to the intercrop understorey offer realizable potential for smallhold farmers in western Kenya and even elsewhere to improve the performance of their maize-legume enterprise.

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