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Rwanda Farming Systems Research Program
Technical Paper Series

ALLEY CROPPING *SESBANIA SESBAN* (L) MERILL WITH FOOD CROPS IN THE HIGHLAND REGION OF RWANDA

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Report # 37

USAID Contract #696-0110
between
The University of Arkansas, Fayetteville
(International Agricultural Programs)
and
The Rwandan Ministry of Agriculture
Rwandan Institute for Agricultural Sciences (ISAR)

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ABSTRACT

Food production in the densely populated Rwandan highlands is impeded by soil erosion and loss in fertility. Alley cropping leguminous shrubs with food crops on contours is purported to minimize the problem and to provide wood and forage as bonus products. This study reports the effect of Sesbania prunings plus moderate levels of N and P on bean (Phaseolus sp) and maize (Zea mays) yields in an alley cropping setting. Experimental design was a randomized complete block with split-split plot arrangement. Main plots were alley width 2, 4, 6 and 8 m. Phosphorus (P) at 0, 30 and 60 kg P_2O_5/ha occupied the subplot and nitrogen (N) at 0, 30 and 60 kg/ha was assigned at the sub-sub plot level. No P was applied to maize during the second cropping season, but N was applied at 0, 20 and 40 kg/ha. Crop yield in kg/ha considered the land space taken by hedgerows. Bean yield in 6-m alleys (1100 kg/ha) was about twice that in 2-m alleys (500 kg/ha). Bean responded to N and P. Optimum alley width and N for bean yield were 6 m and 30 kg/ha, respectively. Cuttings from alley hedgerows provided stakes for climbing beans. Maize responded to N but not to residual P. The highest maize yield came from 8-m alleys with 40 kg N/ha, but yields from 8- and 6-m alleys with the same N treatment were not significantly different. Maize plants in middle rows were significantly taller than plants in rows adjacent to hedgerows. Maize rust development showed significant alley width and row effect. The LSD (0.05) for alley width showed significantly fewer uredinia numbers in the Sesbania alleys relative to the control plots without shrub hedgerows. Rust development on maize in middle rows was significantly greater than development in border rows. Keywords: alley cropping, highland agroforestry, maize, pole bean, Sesbania.

INTRODUCTION

Demographic pressure in the highlands of Rwanda where undeveloped agricultural land is limited calls for high-input agriculture to ensure sustained food production. Inorganic fertilizers are costly, and farmyard manure is not available to all farmers. The employment, therefore, of natural, soil-improving techniques to fix nitrogen and recycle nutrients offers a means to improve crop yields that is cost effective and appropriate for subsistence farming. Alley cropping uses leguminous shrubs to supply N and organic materials and to pump nutrients from the subsoil to the soil surface for crop use (Wilson et al., 1986; Sanchez, 1987). Where soil fertility maintenance or improvement is the principal objective, wood, fodder and fruits are viewed as subsidiary outputs (Wilson and Kang, 1981). On steep slopes, alley cropping is valued more for soil erosion control than for soil fertility improvement (Young, 1984; Lundgren and Nair, 1985).

Sesbania is a leguminous shrub that has been extensively used for agroforestry in several rural development and energy projects in Eastern Africa (KREDP, 1985; KWDP, 1985; ICRAF, 1986). A report by Rotar and Evans (1983) gives a detailed account of the potential of Sesbania as an agroforestry resource for low-input agriculture. Sesbania as well as other leguminous shrubs such as Gliricidia, Calliandra, Tephrosia and Leucaena meets the requirements expected of agroforestry species (Prinz, 1986): fast growth rate, ability to fix N and regeneration after cutting. At the International Institute of Tropical Agriculture (IITA) in Nigeria, Sesbania prunings have been utilized as low-N source material for hydromorphic rice production (IITA, 1984). In the highland areas of Rwanda, Sesbania grows faster than Leucaena, Calliandra and Markhamia. It is currently the most popular woody species among farmers in the Buberuka Highlands of northern Rwanda where the Farming Systems Research Program (FSRP) is located (Yamoah, 1988).

Sesbania is utilized by agricultural development projects for agroforestry in the Rwandan Highlands (Westwood, 1986; Nduwayezu, 1988). In southern Rwanda, however, with an altitude range of < 1400 to 1800 m, rainfall of 850 mm per annum, and a mean temperature of 22 C, Sesbania is not regarded as suitable for alley cropping (Balasubramanian and Sekayange, unpublished). Sesbania was average with respect to coppicing, biomass produc-

tion and tolerance to poor soils. When compared to Cassia, Calliandra and Leucaena, Sesbania was less than average for stake production and resistance to nematodes (Balasubramanian and Sekayange, unpublished). The behavior of Sesbania under intensive management and the effect of Sesbania prunings on crop productivity remain to be determined for the highland region of Rwanda where its initial growth is promising.

This study examines (i) the effect of Sesbania prunings and the moderate use of fertilizer on the performance of pole bean and maize, (ii) the factors that influence regeneration and longevity of the Sesbania under pruning management and (iii) the effect of row position on development of Puccinia sorghii schw.

MATERIALS AND METHODS

The study was conducted on the Rwanda National Agricultural Research Station (ISAR) in the Buberuka highlands where the elevation is 2060 m and rainfall is bimodal with an annual average of 1200 mm. Rains begin in March and continue to June. There is a long dry period from July to September when rains begin again. Rains continue until January when there is a short dry season lasting less than a month. Longitude of the station is East 29°53, and latitude is South 1°32. The mean monthly temperature ranges from < 13 to 17 C. Soils are classified as Oxisols in the USDA soil taxonomy system and are derived from schists and granite parent materials.

The experimental design was a split-split plot. Main plots were alley widths (2, 4, 6 and 8 m). Subplots were P application at rates of 0, 30 and 60 kg P_2O_5/ha. Sub-sub plots were N at rates of 0, 30 and 60 kg/ha. Phosphorus was applied as single superphosphate and N urea. No P was applied to the second maize crop, and N was applied at 0, 20 and 40 kg/ha. Nitrogen for maize was split applied with one-half after emergence and one-half seven weeks after planting. There were two replications with a block size of 800 m^2.

Four-month-old Sesbania seedlings were planted at 0.5-m intervals within rows in April 1986. Shrubs were pruned to a height of 1.0 m in April 1987, and total biomass was weighed. Then small twigs and leaves were separated from the main stem and incorporated into the soil as green manure. Woody stems served as stakes for pole beans (var. Inyumba 3) used as the first test crop. The second cutting of Sesbania hedgerow was made in October 1987, prior to planting maize (var. Bamboo). Small branches and leaves were chopped and incorporated into the soil. The third cutting in April 1988 was treated similarly to the second. There were check plots outside the hedgerows without prunings and fertilizer. The number of surviving Sesbania was counted after the third cutting.

During season two for maize, leaf number/plant, number of leaves/plant infected by Puccinia sorghi Schw. and number of P. sorghi uredinia/leaf were counted on 90 plants each in border and middle rows of 2-, 4-, 6- and 8-m alleys to determine the effect of Sesbania alley width on rust development. Observations also were made on the same maize variety (Bamboo) in an adjacent, open field so comparison could be made among alley widths of 0, 2, 4, 6 and 8 m. Area under diseased leaf progress curve (AUDLPC) was calculated (Shaner and Finney, 1977) using proportion of infected leaves/plant and days between observations. Counts were made on four occasions during the growing season.

The effect on maize of shading by Sesbania was evaluated by measuring maize height in border and middle rows of each alley. Yield was recorded as kg/ha and adjusted for land area occupied by shrubs. The above adjustment was based on food crop row spacing (S) and alley width (W) and is given by the relation

$$Yaj = (1-S/W) * Ya * 10{,}000/(W * L),$$

where Yaj is adjusted yield in kg/ha, Ya is the unadjusted yield in kg/plot, and L is the length of a plot. Data were analyzed by using the MSTAT statistical package, and interpretations were based on both statistical significance (LSD at 0.05) and on our experience with the local farming systems.

RESULTS AND DISCUSSION

Bean Performance

Bean response to N in alleys is shown in Fig. 1. In narrow alleys (2- and 4-m) the response was not significant. In 6-m alleys, yields from plots receiving 30 and 60 kg N/ha were significantly greater than yields from plots where no N was applied. Yields from plots receiving 30 and 60 kg N/ha were not significantly different. Beans responded to N in 8-m alleys. Yields from plots receiving 60 kg N/ha were significantly greater than yields from plots receiving 30 and 0 kg/ha. In 8-m alleys, prunings were spread over a relatively larger area than in 6-m alleys, thereby reducing the effect from prunings. Fertilizer is required, therefore, to increase yield in wide (> 8 m) alleys.

Analysis of variance showed no significant difference among alley widths (main plots). That is because larger block sizes (800 m^2) limited the number of replications to only two. Larger block sizes were used to enable a realistic

assessment of labour requirements essential for the development of the technology. In absolute terms, there was more than a 100% increase in bean yield between 6- and 2-m alleys with the same level of N (Fig. 1). Farmer acceptance of an improved intervention is put at about 20% increase over an existing one (Steiner, 1987). Our knowledge of local farming systems convinces us that farmers would be more than willing to adopt 6- or 8-m alleys instead of 2-m width as a result of the observed yield differences. For farmers with sufficient cash and land, use of 8-m alleys and about 60 kg N/ha would be an efficient way to achieve adequate and sustained production.

Farmers are not likely to accept 2- and 4-m alley widths because of excessive land lost to crop production and because of crop shading by hedges. The 2- and 4-m alleys could serve either as fodder banks or woodlots on very steep slopes where normal cultivation of arable crops is inadvisable.

Bean yield increased with P application (Fig. 2). Yields at 60 kg P/ha were significantly greater than at 0 kg P/ha, but yields at 60 and 30 kg P/ha were not significantly different. The application of 30 kg/ha each of N and P gave 300 kg/ha more bean yield than application of prunings alone. With 30 kg N and 60 kg P/ha, bean yield was 600 kg/ha greater than with prunings alone.

Fertilization at early stages of hedgerow establishment is indispensable, particularly on impoverished soils such as we have in the Buberuka Highlands of Rwanda. On poor soils, shrub growth is slow, and plants are stunted and chlorotic (Yamoah, 1988) as there are virtually no nutrients in the subsoil. Fertilizer application at the time of planting, therefore, would promote rapid early shrub growth and perhaps enable farmers on poor soils to more readily profit from this technology. Sanchez and Benites (1987) made a similar recommendation with respect to use of starter lime on acid soils in the Amazon region.

The economic advantages of inorganic fertilizer used by resource-poor farmers for alley cropping in the Rwandan Highlands remains to be determined. Economic analysis should consider in-situ production of stakes for pole beans supplied by the hedgerows. In fact, it is the stake-production aspect of alley cropping that first lures farmers to plant Sesbania hedges.

Maize Performance

Figures 3 and 4 show maize height in alleys before and after top dressing with N. Maize height differed with levels of N before top dressing. Maize height in plots treated with 20 kg N/ha was significantly greater than height in plots with prunings alone (0 N). Top dressing rendered insignificant height differences among treatments, and that effect could be attributed to a temporary drought that set in after top dressing, adversely affecting N uptake by maize. Competition for water results in adverse effects of alley shrubs on intercrops under moisture stress conditions (ICRISAT, 1987).

The effect of alley width on maize performance was evident only after top dressing (Fig. 3). The hedgerows had been pruned just prior to top dressing; therefore, shading from Sesbania was less severe before top dressing than after when new growth was present. Plants were not pruned during the growing seasons, March-June and September-January.

Figure 4 shows that maize in middle rows was significantly taller than maize in border rows (i.e. adjacent to Sesbania hedges). The trend persisted throughout the growing season. The interaction of N and row position was significant before but not after top dressing. Adequate soil moisture and less shading might have resulted in high N use efficiency by maize before top dressing. In an area with erratic rainfall, a second pruning could be done during the growing season and the pruned materials used as mulch to conserve soil moisture. Nevertheless, Sesbania will not survive a dry period when all leaves are removed.

Figure 5 shows the response of maize to N in alleys. Maize responded to N fertilization in all alleys except those of 2-m width. The yield response of maize to application of 40 kg N/ha was significant only in 8-m alleys. Again, the dilution effect of prunings in the wider (8-m) alleys was responsible for the fertilizer effect. The N levels selected for this study are similar to levels of N applied by farmers to their fields as manure in our zone of operation.

Supplementary nutrients from external sources such as manure and inorganic fertilizers can interact positively with N from prunings to boost crop yield. In Rwanda, Neumann and Pietrowicz (1983) obtained maize yields of 1254, 2834, 3312 and 3044 kg/ha from plots treated with 15 t manure, 10 months legume fallow, legume fallow plus manure and 120, 100 and 100 kg/ha NPK, respectively. At IITA, maize yield in plots with Leucaena prunings plus 40 kg N/ha averaged 3 t/ha in contrast to a yield of 2 t obtained from plots where only 120 kg N/ha were applied (IITA, 1985). Soil fertility improvement from alley cropping is a slow but continuous process. Therefore, the quantity of fertilization needed from external sources should diminish over time.

Rust on Maize

Analysis of common maize rust development shows significant alley width and row position effects (Table 1). The proportion of infected leaves/plant, numbers of uredina/plant and AUDLPC from maize in 0-m alleys (open field) were significantly greater than from maize in 2-, 4-, 6- and 8-m alleys. There were no significant differences between alley widths of 2, 4, 6 and 8 m. Rust development on maize in middle rows was significantly greater than development in border rows. Although preliminary, these results suggest that Sesbania alleys might effectively limit development of some foliar pathogens in crops. Yield loss due to disease is a function of rate and duration of disease development. Therefore, if foliar disease development on crops is slowed by alley cropping with Sesbania, then yield loss might be reduced as well. In this experiment, P. sorghi was not severe enough to cause damage. It is premature, therefore, to claim that alley cropping plants will prevent or lessen yield loss from foliar pathogens. Nevertheless, the results of this study show that development of common maize rust was less in alleys than in open fields, implying, therefore, that crop damage by disease would be less as well.

Mortality of Sesbania

Percent mortality of Sesbania after three cuttings in two years was assessed. Sesbania height was maintained at 1.0 m and about 25% of foliage was retained on the stock to permit photosynthesis. Percent mortality per 40-m row of Sesbania (81 plants) ranged from 2 to 20% with a mean of 10%. Sesbania does not have a solid wood stem as does Leucaena and, therefore, is not able to store enough carbohydrates to facilitate regeneration after pruning (Garrison, 1971). In Rwanda, Yamoah (1988) found that the following management practices were associated with Sesbania mortality: 1) removal of all leaves in a relatively low altitude (< 1500 m) and warm (> 22 C) environment, 2) coiling of seedling roots prior to transplanting, 3) pruning below a height of 50 cm, particularly for plants over 12 months old and 4) pruning at the end of the rainy season (an exception is plants in moist valleys).

Although Sesbania is susceptible to nematodes (Rotar and Evans, 1983), their effect on Sesbania growth in Rwanda is unknown. However, in banana-growing agroecological zones such as this one, nematodes are common, and they could affect growth of Sesbania. In general, growth of Sesbania on eroded hillsides is mediocre, and plants if mismanaged are more likely to die than their counterparts in moist, rich valley soils. As a management strategy, the fast-growing but delicate nature of Sesbania makes it logical to recommend its mixture in a hedgerow with Leucaena, which is a more robust species. Farmers are urged to maintain Sesbania nurseries so that dead plants can be replaced.

Biomass Production

Figure 6 shows fresh Sesbania biomass production for 25 months. Biomass of prunings at 12, 18 and 25 months after planting averaged 6.6, 2.3 and 9.2 kg/m, respectively. There was a significant difference in biomass yield between narrower (2- and 4-m) alleys and wider (6- and 8-m) alleys for the first pruning. Biomass yield among alleys did not differ for the second pruning. There were significant differences in biomass production among cutting periods. Biomass from the first pruning was significantly higher than that harvested 6 months later. Biomass yield between the second and third prunings also differed significantly. Biomass yields from the first and third prunings were not significantly different. The relatively high biomass obtained from the third pruning might be due to adequate rainfall that normally occurs between October and April. Sesbania produced many branches following cutback, raising its biomass yield in subsequent cuttings.

Low vegetative yield from the second pruning was the result of drought. The dry season is from June to September; therefore, there was only one month (May) of adequate rainfall for shrubs to regenerate after the first pruning. Drastic fluctuations in biomass yield noted above suggest that pruning Sesbania once/year in October would stabilize biomass production by allowing sufficient time for regrowth after cutting. In addition, cutting once/year could prolong shrub life. In that case wider alleys (6 and 8 m) would be preferred to minimize crop shading.

CONCLUSION

Sesbania is a promising woody species for agroforestry land use in the highland region of Rwanda where altitudes range from 1500 m to over 2400 m. Prunings of Sesbania in combination with moderate quantities of N and P increased yields of pole beans and maize in the wider (6- and 8-m) alleys. Intercrop yields in narrow (2- and 4-m) alleys were low due to greater cultivable area sacrificed to shrubs and to shading by hedgerows.

Shading is a serious problem with Sesbania as complete removal of foliage kills the shrub. Mortality rate of Sesbania is low once established, but care is required to ensure shrub longevity. There are reports that mortality of Sesbania is affected by nematode infection, but there is no evidence for this relationship in Rwanda. Alley cropping might reduce the impact of foliar plant pathogens on crop yield by slowing disease development.

From a management standpoint, shrubs should be pruned once a year when rainfall is adequate and reliable to enhance biomass production. Economic appraisal is necessary to determine if Sesbania alley cropping with these inputs is a viable and feasible alternative for the resource-poor farmers who dominate in the region. The economic analysis should also consider the value of in-situ stakes that are provided by hedgerows and that are used for pole bean production. Indeed, it is this aspect of alley cropping technology that attracts farmers to plant Sesbania.

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Table 1. Proportions of maize leaves per plant infected by Puccinia sorghi, number of P. sorghi uredinia per leaf and area under the diseased leaf progress curve (AUDLPC) for border and middle rows of maize (Bamboo precoce) grown in Sesbania alleys of 0-, 2-, 4-, 6- and 8-m widths in Rwanda.

Alley width (m)	Proportion infected leaves/plant	No. P. sorghi uredinia/leaf	AUDLPC
0	0.98a	150a	71.4a
2	0.78b	59b	56.4b
4	0.78b	42b	55.6b
6	0.83b	56b	57.4b
8	0.79b	45b	55.4b
Row position			
Middle	0.98a	130a	72.2a
Border	0.77b	58b	54.3b

ab Means within a column followed by the same letter are not sinificantly different (P = 0.05) according to the FLSD test.

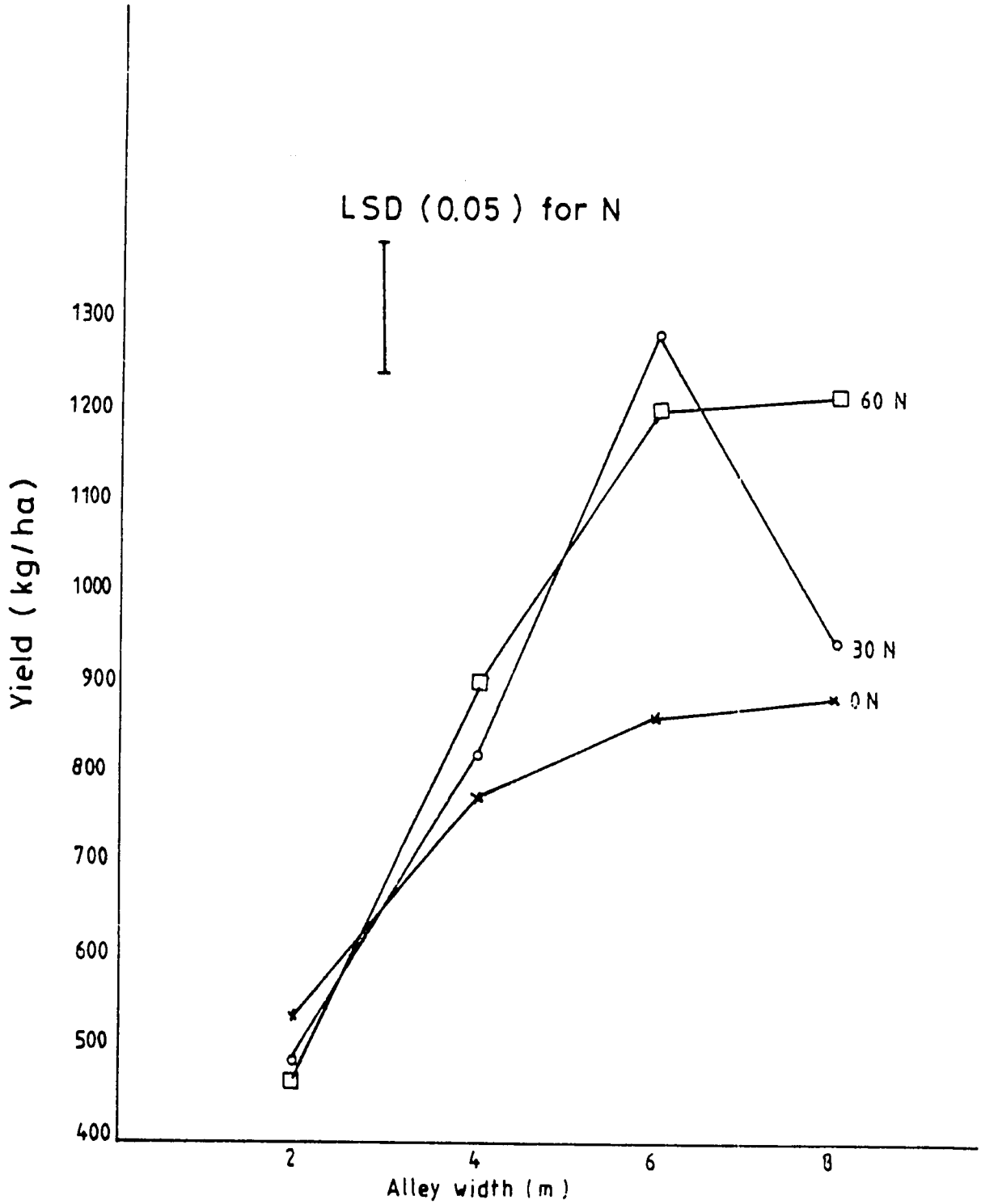

Fig. 1. Effect of alley width on the response of beans to N.

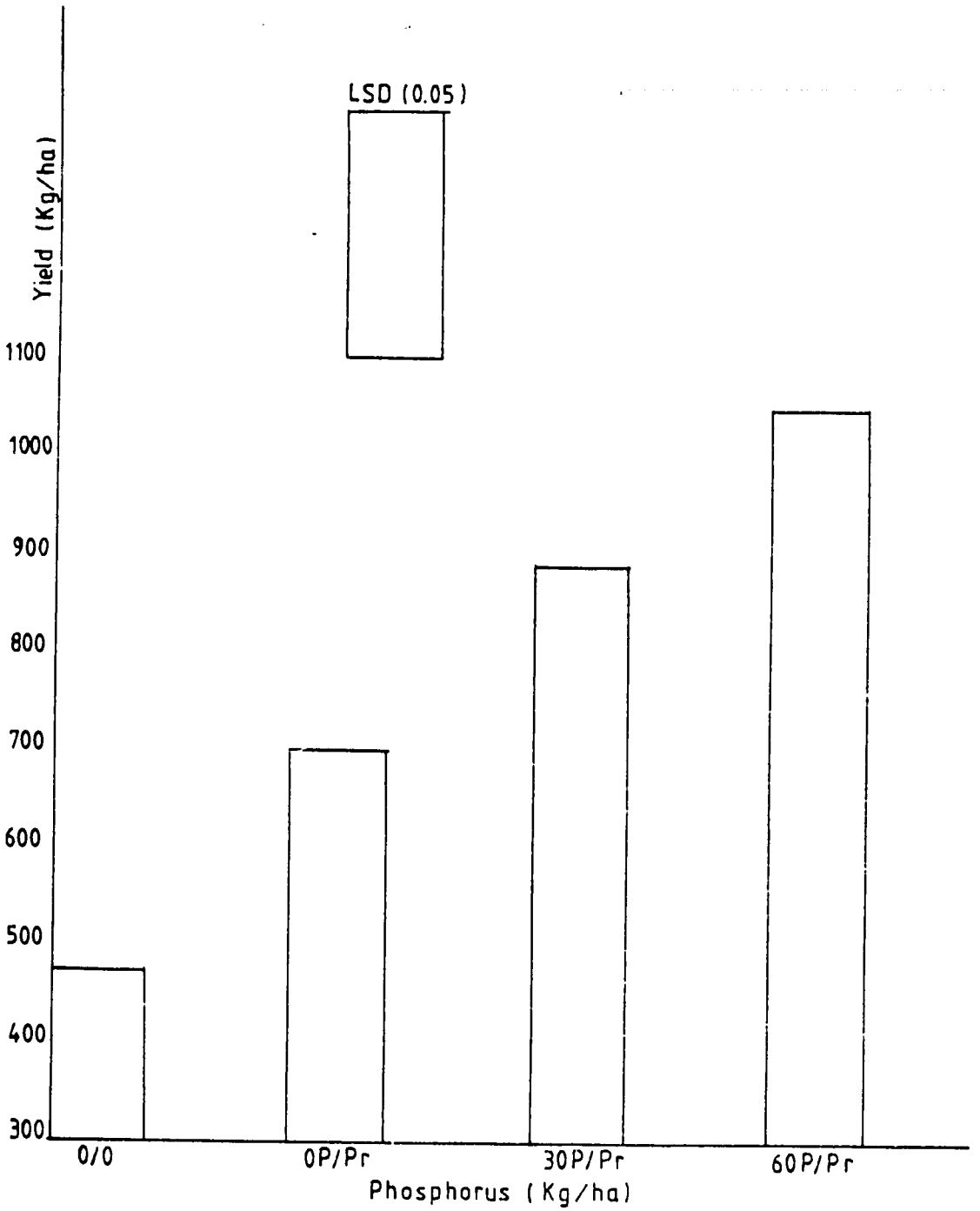

Fig. 2. Effect of phosphorus and prunings (Pr) of Sesbania on yield of pole beans.

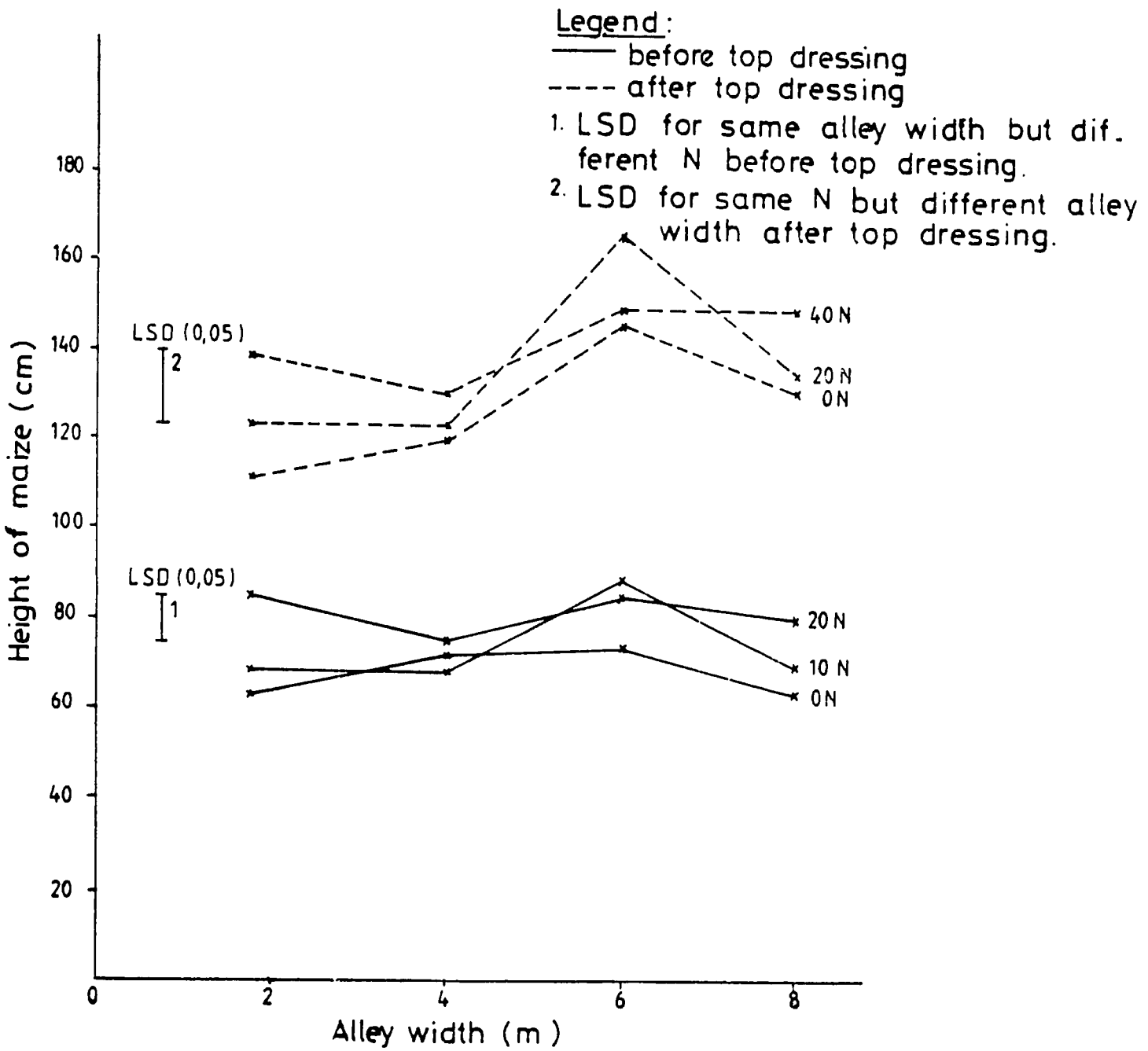

Fig. 3. Effect of alley width and N on maize height before and after top dressing with fertilizer N.

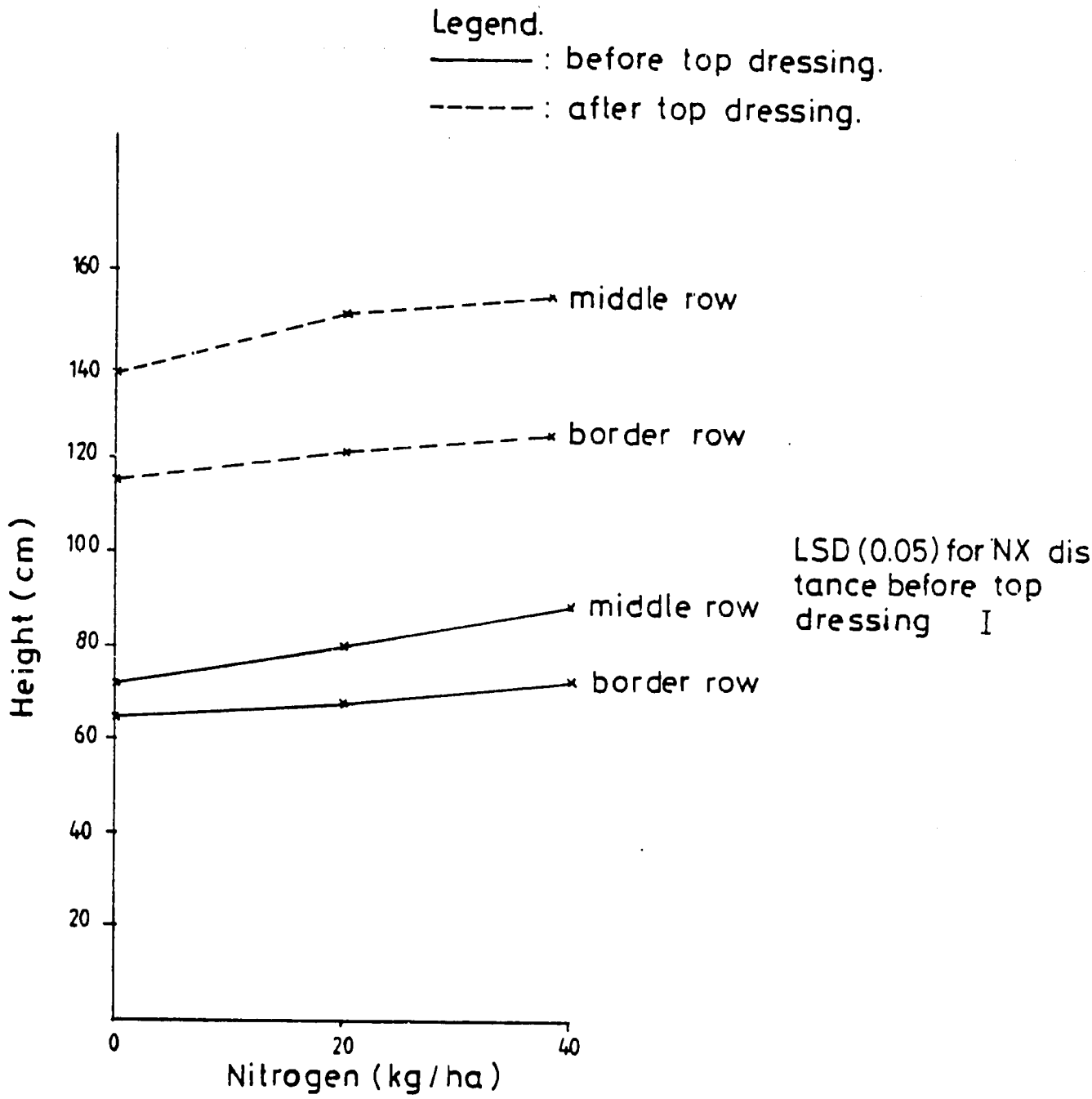

Fig. 4. Interactive effect of N and distance from hedgerow on maize height.

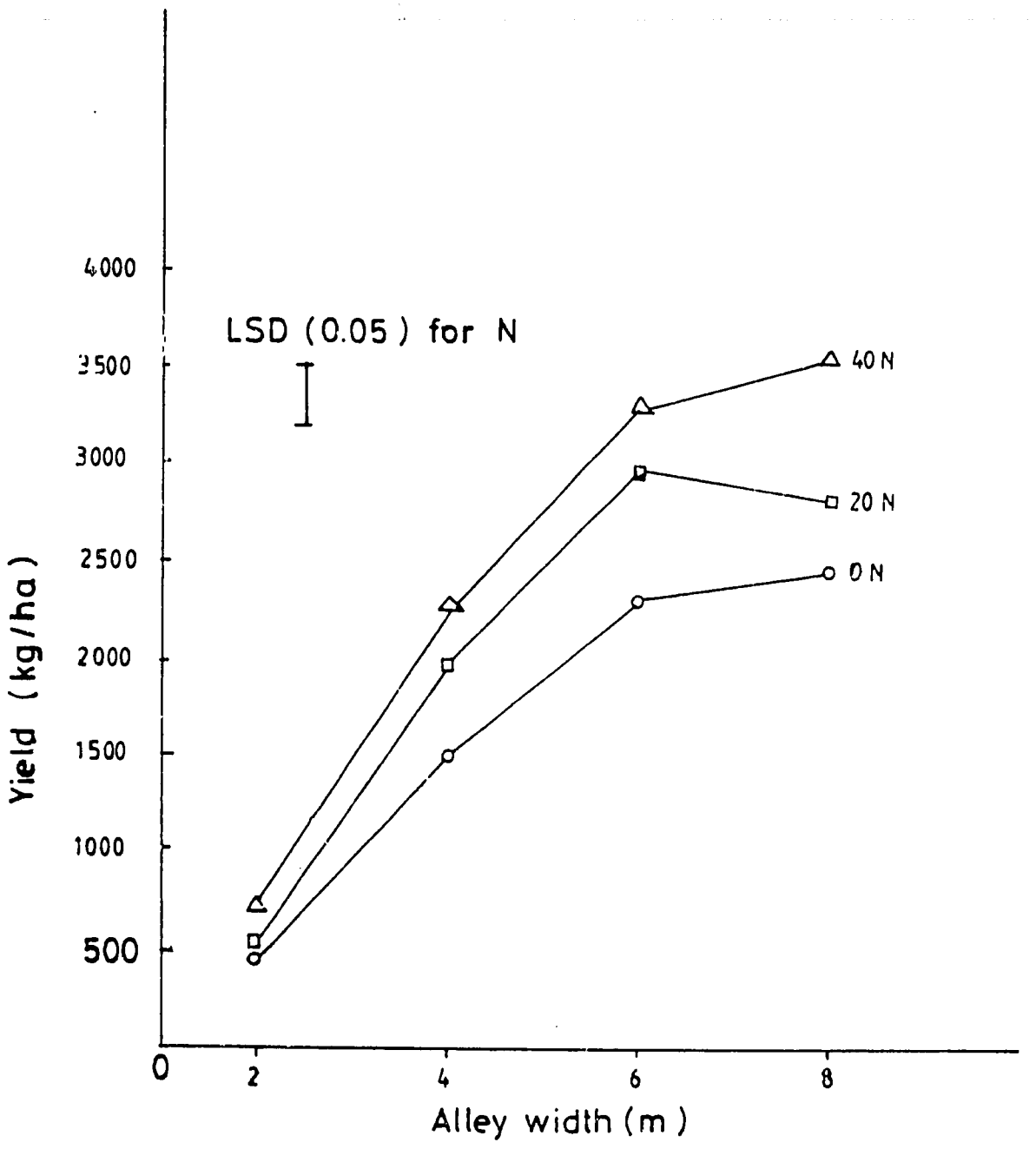

Fig. 5. Maize response to N in different alley widths.

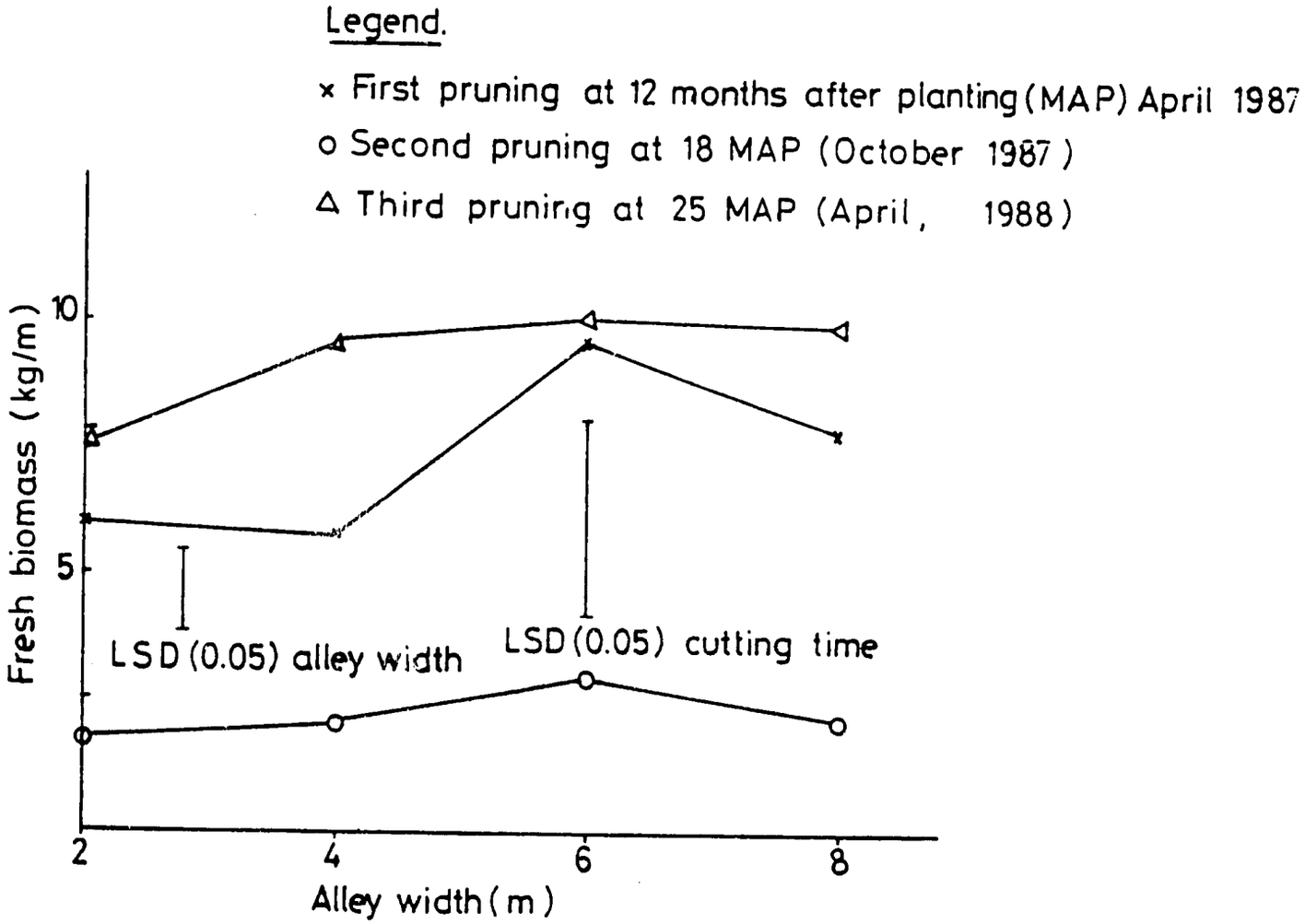

Fig. 6. Fresh biomass production of Sesbania as affected by alley width and period of cutting in the highland region of Rwanda.