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GROWTH ANALYSIS OF COMPONENT CROPS IN A MAIZE-SOYBEAN INTERCROPPING SYSTEM AS AFFECTED BY TIME OF PLANTING AND SPATIAL ARRANGEMENT

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ABSTRACT

Two field trials were conducted in 2007 and 2008 to determine the appropriate sequence of planting and spatial arrangement for the maize-soybean intercropping system for optimum growth. The experimental design was a randomized complete block design with three replicates. Treatments consisted of combinations of five relative times of planting either maize or soybean and two spatial arrangements of soybean (alternate or double rows). One sole crop each of maize and soybean was added for comparison. Results of the growth analysis indicated that maize planted simultaneously with soybean or before soybean recorded significantly higher values of leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR). Spatial arrangement did not influence these parameters in maize. Interaction between time of planting and spatial arrangement was however significant. LAI and CGR for maize increased with time while NAR declined. For the soybean crop, soybean planted on the same day with maize or planted before maize recorded significant LAI, CGR and NAR values. Soybean planted in double row arrangement with maize recorded significant higher growth than soybean planted in alternate row arrangement with maize.

Keywords: maize, soybean, intercropping, growth analysis, planting time, spatial arrangement.

INTRODUCTION

Many and diverse cropping systems have been used and in some cases continue to be used to bring about increased food production in Africa. One of these systems is intercropping, the growing of two or more crop species simultaneously in the same field during a growing season (Ofori and Stern, 1987). Common characteristics of different forms of intercropping are that they have the advantage of exploiting environmental resources more efficiently (Francis, 1989; Li *et al*., 2003; Zhang and Li, 2003; Li *et al*., 2006), improving soil fertility (Shen and Chu, 2004; Dahmardeh *et al*., 2010) and increasing crop yield and quality (Javanmard *et al*., 2009; Dahmardeh *et al*., 2010).

According to Koli (1975), almost every peasant farmer in Ghana practices mixed cropping. In the forest areas, young cocoa plants are intercropped with plantains and cocoyam to give shade to the cocoa plants. Cassava is intercropped with maize so that after the latter is harvested, the young cassava can continue to occupy the land. Many vegetables, such as garden eggs, tomatoes and peppers are also intercropped with food crops all over the country. In the Northern and Upper Regions, early millet is intercropped with sorghum (guinea corn); legumes, such as groundnuts, bambara nuts and cowpea are intercropped with sorghum or maize. It is obvious that intercropping has some advantages for peasant farmers whose farm operations are labour-intensive and who use simple tools for cultivation on smallholdings.

Combinations of crops are determined partially by the length of the growing season and the adaptation of crops to particular environments. In areas with annual rainfall of less than 600 mm and a short growing season, such as Northern Nigeria, early maturity and drought tolerant crops such as millet and sorghum dominate (Andrews, 1972; Baker, 1979). In areas with annual rainfall greater than 600 mm, cereals and legumes of varying maturities are used. In the tropical and subtropical regions, the cereals component is usually maize, sorghum, and millet or to a lesser extent, rice, and the legume is usually cowpea, groundnut, soybean, chicken pea, bean or pigeon pea. Both early and slow maturing crops are combined to ensure efficient utilization of the growing season (Baker, 1979).

Maize seems to dominate as the cereal component and its combination with soybean is becoming very popular among the small scale farmers in certain parts of Ghana. This is because of the nutritive and economic importance of the latter. When grown in associations with maize, it would provide high carbohydrate and protein diets for the people. Nevertheless, some farmers cultivate soybean commercially as a sole crop, especially in the savanna zones of the Northern and Upper Regions. This indicates that the farmers in these major growing areas are still not exploiting the beneficial effects of the legume in intercropping systems.

The relative time of planting of the intercrop before, at the same time or after the main crop has both biological and practical implications. For example, differential sowing minimizes competition for growth limiting factors as peak demand for these factors occur at different times. Also it ensures full utilization of growth factors because crops occupy the land throughout the growing season. Similarly, spatial distribution in the field is of great importance when intercropping two or more species, since it affects the efficiency with which solar radiation and space are utilized. Furthermore spatial arrangement has an important influence on the degree of competition between crops. However, relative time of planting and spatial arrangement of soybean grown in association with maize in Ghana has not been extensively studied and not well documented. The general objective of the present study was to establish the appropriate sequence of planting and spatial arrangement for the maize-soybean intercropping system for optimum growth.

MATERIALS AND METHODS

Site description

The experiments were carried out at the Teaching and Research Farm of the University of Cape Coast, Cape Coast from October 2007 to January, 2008 (Experiment 1) and from June to October, 2008 (Experiment 2). Rainfall in this area ranges between 800mm and 1000mm annually. It has a bimodal rainfall pattern. The major season occurs from March to July, with maximum in June and minor season from September to November, with maximum in October. Between 60-70% of the total annual rain falls in the major season and 30-40% in the minor season (Asamoa, 1973). The mean monthly temperature is about 26.5^0C. The soils of the area are sandy clay loam, belonging to Benya series, which is a member of the Edina-Benya-Udu compound association, developed under Sekondian material. They are classified as Typic Haplustult (USDA Soil Taxonomy) and Haplic Acrisol (FAO/UNESCO).

The site during the minor season (Experiment 1) was previously planted with cowpea. The site for the major season (Experiment 2) was previously planted with maize.

Planting material

One variety each of maize and soybean was used. The maize variety was Obatanpa and the soybean variety was Anidaso. Obatanpa is a white dent, medium-maturing (105-110 days) variety. It has a plant height of 175cm and an average grain yield of 4.5 ton/ha (CRI, 1990). The soybean variety (Anidaso) is resistant to shattering, nodulates freely with the indigenous cowpea/groundnut rhizobia in Ghanaian soils. It matures in 105-115 days, with a plant height of 35-40cm and yields 1.2-1.8 ton/ha (CRI, 1994).

EXPERIMENTAL PROCEDURE

Experimental design

The experiments were set up in a randomized complete block design (RCBD) with three replications. Treatments consisted of combinations of five relative times of planting either maize or soybean and two spatial arrangements. Each plot measured 6.4m x7.2m. One sole crop each of maize and soybean was added for comparison. Treatment details are provided in Tables-1 and 2. The additive series, in which mixtures have been achieved by adding together the plant populations used in the pure stand treatments, was used.

Table-1. Treatment combinations and times of planting.

Treatment code	Description
T_1S_1	Maize planted same day with soybean, soybean in alternate rows
T_1S_2	Maize planted same day with soybean, soybean in double rows
T_2S_1	Maize planted 14 days before soybean, soybean in alternate rows
T_2S_2	Maize planted 14 days before soybean, soybean in double rows
T_3S_1	Maize planted 28 days before soybean, soybean in alternate rows
T_3S_2	Maize planted 28 days before soybean, soybean in a double rows
T_4S_1	Maize planted 14 days after soybean, soybean in alternate rows
T_4S_2	Maize planted 14days after soybean, soybean in double rows
T_5S_1	Maize planted 28 days after soybean, soybean in alternate rows
T_5S_2	Maize planted 28 days after soybean, soybean in double rows
Sole maize	Sole maize
Sole soybean	Sole soybean

Table-2. Plant spacing and expected population density for maize and soybean.

Plant	Spacing	Plants/Hill	Expected No. of plants	
			m^2	Ha
Maize	90cm x 40cm	2	5.55	55, 555
Soybean	90cm x 20cm	2	11.11	111,111
	45cm x 20cm	2	22,22	222,222

Planting and cultural practices

The field was ploughed and harrowed just before planting. Planting was done between 8/10/2007 and 5/11/2007 for Experiment 1 and 25/6/2008 and 23/7/2008 for Experiment 2. Maize was planted 3 seeds per hill and thinned to 2 seeds per hill; soybean was planted 4 seeds per hill and thinned to 2 seeds per hill. During Experiment 2, rainfall was very low. The field was therefore irrigated once every week during the period of the trial. Fertilizers were applied only to maize. NPK 15-15-15 fertilizer at the rate of 250 kg per hectare by side placement 2 weeks after planting, urea at 125 kg per hectare was applied top dressed six weeks after planting. Total fertilizer nutrients applied therefore worked up to 95.0.N; 37.5 P_20_5; 37.5K_2O kg/ha. The plots were weeded during the 2nd, 4th and 7th week after planting.

Parameters measured

i. Leaf area was determined as described by Edje (1988). From that, the leaf area index was obtained as:

Leaf area index (LAI) = L/P

where L is the leaf area and P is the ground.

Other growth parameters were calculated on the net plot sample area of 2.16m^2 using established formulae (Radford, 1967; Buttery, 1970) shown below:

ii. Crop growth rate (CGR, g^{-2} day^{-1}):

$$= \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

where W_1 and W_2 are the total plant dry weight at time t_1 and t_2, respectively and P is the land area.

iii. Net Assimilation rate (NAR, g^{-2} day^{-1}):

$$= \frac{W_2 - W_1}{t_2 - t_1} \times \frac{InL_2 - InL_1}{L_2 - L_1}$$

Where W_1, W_2, t_1 and t_2 are as in (ii) above and L_1 and L_2 are the leaf areas at times t_1 and t_2.

RESULTS AND DISCUSSIONS

Leaf area index (LAI) - Maize

Experiment 1 indicated a gradual increase in LAI from the 5th to the 9th week and thereafter it declined (Figure-1). Maize planted simultaneously with soybean or before soybean (T_1-T_3) recorded higher values of LAI than maize planted after soybean. During the 9th week, maize planted 28 days after soybean (T_5) recorded the least LAI. Spatial arrangement did not influence maize LAI. Interaction between time of introduction of soybean and spatial arrangement showed significance from the 7th week sampling. Sole crop recorded higher values of LAI than the intercropped mean. The results of Experiment 2 showed similar trend as those recorded for Experiment 1 (Figure-1). Treatment T_3S_1 recorded the highest value while the least value was observed for treatment T_5S_2. Generally, Experiment 2 recorded higher significant values than those recorded for Experiment 1.

Leaf area index describes the size of the assimilatory apparatus of a plant stand and is the primary factor that determines the rate of dry matter production in a closed stand. It also reflects differences in productive efficiency between crop varieties (Kvet *et al*., 1971). LAI was larger for maize introduced before soybean than those introduced after soybean. Osafo (1976) recorded 1.5 to 6.2 for LAI for maize in Kumasi, depending on the period of the year it was planted. In this study, the lower LAI recorded for maize introduced late into the intercrop indicated lesser growth as a result of severe competition for resources of growth with soybean. Water stress easily leads to rapid leaf senescence and leads to reduction in the LAI. Littleton *et al*., (1979) indicated that under non-drought conditions, each leaf has a well-defined growth rate, which is a function of temperature and maximum leaf area. Competition for resources e.g., water could possibly be the most important growth resources in this trial that limited LAI in the late introduced maize crop. Spatial arrangement and its interaction with time of introduction of maize did not affect LAI because soybean density did not affect the growth of maize.

Crop growth rate (CGR) - Maize

Generally, CGR rose to a maximum for H_3-H_2 and then declined for H_4-H_3 (Figures 2a and 2b). Time of introduction significantly influenced CGR in Experiment 1. Maize planted 28 days after soybean (T_5) consistently recorded the least values for H_3-H_2 and H_4-H_3 samplings. Generally, spatial arrangement did not significantly influence CGR except for H_2-H_1 (Figure-2c). Interaction between time of introduction of soybean and spatial arrangement was only significant between the 9th and 11th week (H_4-H_3). Treatment T_3S_1 recorded the highest CGR while treatment T_5S_1 gave the lowest. CGR for sole crop was higher than the mean of the mixed plots.

In Experiment 2 the effect of time of introduction of soybean recorded significance for all harvests (Figure-2a). Low values were consistently recorded by maize introduced after soybean was planted. Spatial arrangement significantly influenced crop growth rate at the second (H_3-H_2) and third (H_4-H_3) harvesting periods (Figure-2d). Interaction between time of introduction of soybean and spatial arrangement was also significant (2f). Treatment T_3 S_1 recorded the highest value while the least value was recorded by treatment T_5S_1. Sole crop values were higher than the means of the mixed crop. Experiment 2 values were generally higher than values for Experiment 1.

According to Clawson *et al*., (1986), CGR measures the accumulation of dry matter per unit area and is a reasonable approximation of canopy photosynthetic rate per unit ground area. A range of -2.5 to 17.3 at 76-90 days, depending on the period of the year planting was done was recorded for maize in Kumasi (Osafo, 1976). In this study a range of 1.96 to 16.94 was recorded for maize depending upon time of introduction of maize. Generally, maize planted simultaneously with soybean or planted before soybean recorded higher values of CGR than maize planted after soybean.

In the present study, there was a general increase in CGR as LAI increased. The slight fluctuations in CGR experienced in some cases were probably due to competition for resources, e.g. light, soil nutrients and water from weeds. Dry matter production is encouraged by increasing amount of light intercepted. Maize introduced after soybean were partially shaded by the soybean, especially maize planted 28 days after soybean. This resulted in low values of CGR.

Net assimilation rate (NAR) - Maize

In Experiment 1, net assimilation rate declined from H_2-H_1 to H_4-H_3 (Figure-3). Time of introduction of soybean recorded significant differences among the treatments from H_2-H_1. Treatment T_3 recorded the highest NAR while treatment T_5 recorded the least. Spatial arrangement significantly influenced NAR only for H_2-H_1, where S_2 recorded a higher NAR than S_1. Similarly the interaction between spatial arrangement and time of introduction of soybean was significant for all harvests. Treatment T_3S_1 recorded the highest NAR with treatment T_5S_2 recording the least. Sole maize recorded slightly higher values of NAR than the intercropped mean. Experiment 2 showed similar trends as in Experiment 1.

NAR generally declined at successive harvests in maize. Differences in NAR as affected by time of introduction of maize were only evident at the final harvests for Experiment 1 and the last two harvests for Experiment 2 (Figure-3). Osafo (1976) gave values of NAR ranging from 3.6 to 5.0 at 76-90 days after planting maize in Kumasi, depending on the time of planting during the year. According to Watson (1958), as LAI increases, mutual shading of the leaves would at some time be expected to decrease photosynthesis by part of the foliage, and so to decrease NAR. This occurs even in bright sunshine because an increasing fraction of the leaf area would be illuminated by light intensities below saturation value. In this study, the difference in NAR due to differences in time of introduction of maize into the intercrop was possibly due to a rise in shading experienced more by the late introduced crop than the early ones. The reduction in light leads to decreasing rates of photosynthesis. Spatial arrangement generally did not influence NAR. This is because the maize plants were generally tall and suffered no great shading from neighbouring soybean plants.

Leaf area index (LAI) - Soybean

In Experiment 1, LAI increased gradually from the 5th to the 11th week (Figure-4). The effect of time of introduction of maize on LAI was significant on all samplings (Figure 4a). Generally, soybean planted on the same day with maize (T_1) or planted before maize (T_4 and T_5) recorded higher significant LAI than soybean planted after maize (T_2 and T_3). Soybean planted in double row arrangement with maize (S_2) recorded significantly higher values than soybean planted in alternate row arrangement with maize (S_1) (Figure-4c). There were significant interactions between time of introduction of soybean and spatial arrangement for H_1 and H_3 (Figure-4e). T_5S_2 recorded the highest value of LAI while T_3 S_1 recorded the lowest values throughout the period of investigation. Experiment 2 recorded similar results as those obtained for Experiment 1 (Figures 4b, 4d, 4f).Values of LAI for Experiment 2 were generally higher than those recorded for Experiment 1.

Soybean planted before maize or simultaneously with maize recorded higher LAI than those planted after the introduction of maize. The poor performance of soybean when planted, especially after maize, is probably due to shading by the taller maize crop so that bean growth was limited by reduced light intensity. Shibles and Weber (1965) and Gardiner and Craker (1981) obtained similar results. Soybean in double rows recorded higher LAI than those in single rows. Enyi (1973) obtained similar results when he observed an increase in LAI with increasing soybean population. Maximum LAI was obtained in the higher soybean populations 2 weeks before those of the lower population. With higher population, greater number of leaves was produced and this led to higher LAI in the plots with double rows of soybean.

Crop growth rate (CGR) - Soybean

In both experiments CGR increased from H_2-H_1 to H_4-H_3 (Figures 5a, 5b). In Experiment 1, time of introduction of maize and its interaction with spatial arrangement significantly influenced CGR at H_3-H_2 and H_4-H_3 (Figures 5a, 5e) whereas in Experiment 2 their effects were shown throughout the sampling period (Figures 5b, 5f). Spatial arrangement significantly affected CGR at the last sampling date (H_4-H_3) in both experiments (Figures 5c, 5d). Soybean planted on the same day as maize (T_1) or planted before maize (T_4 and T_5) recorded higher values for CGR than soybean planted after maize. Soybean planted in double row (S_2) recorded higher significant CGR than those planted in alternate row arrangement (S_1). T_5 S_2 consistently recorded the highest CGR while T_3 S_1 recorded the lowest. Values of CGR for sole crop were always higher than the intercropped mean. Values for Experiment 1 were generally not different from values for Experiment 2.

Soybean CGR rose gradually from 1st to the 4th harvest. Soybean planted simultaneously with maize or planted before maize recorded higher values of CGR than those planted after maize. Studying alterations in plant growth and dry matter distribution in soybean, Egli (1988) observed that shade treatments caused large reduction in CGR. Shibles and Weber (1965) also observed that CGR is a linear function of intercepted irradiance. In this study soybean planted after maize suffered lot of shading from the earlier planted taller maize plant. Low LAI was produced leading to reduced photosynthesis, hence lower CGR.

Soybean in double rows recorded higher values of CGR than those in single rows. Studying effects of population on growth and yield of soybean, Enyi (1973) observed that because dry matter production was encouraged by increasing amount of light intercepted, CGR was increased linearly with the increase in light intercepted as a result of increasing LAI. He noted that mean CGR for sampling periods increased with increasing plant density. In this present experiment, doubling soybean rows led to increased LAI, which was able to capture more Photosynthetic Active Radiation (PAR) for greater photosynthesis, leading to greater rate of dry matter accumulation. Higher values of CGR for sole crop than the intercropped mean indicated that sole crop was exposed more to PAR than those in the intercrop. Reduction of 45% and 37% for the mean compared with sole crops were observed for Experiments 1 and 2, respectively.

Net assimilation rate (NAR) - Soybean

The effect of time of introduction of maize significantly affected NAR (Figure-6). Soybean planted with maize (T_1) or before maize (T_4 and T_5) recorded higher NAR at H_3-H_2 and H_4-H_3 sampling dates than soybean planted after maize (T_2 and T_3). Spatial arrangement generally did not significantly influence NAR except for H_3-H_2 where S_1 recorded a bigger NAR than S_2 (Figure-6c). Interaction between time of introduction of maize and spatial arrangement recorded significant effect on NAR. In Experiment 1, T_1S_1 recorded the highest value at the first two sampling dates, while T_1S_2 showed the highest NAR at H_4-H_3 (Figure-6e). Net assimilation rate for the sole crops were not significantly different from the means of the mixed stands. Experiment 2 results were similar to those in Experiment 1 (Figures 6b, 6d, 6f) except for the interaction effect on NAR where no uniform trend was observed. Experiment 1 recorded significant higher NAR values than Experiment 2.

NAR declined as the season progressed. Soybean introduced earlier than maize or simultaneously planted with maize recorded higher values of NAR than those introduced late into the intercrop. A rise in shading due to increase in LAI accounted for the decline. Also late introduced plants suffered more shading by maize than those introduced early. Buttery (1969) noted a decline in NAR as the season progressed and attributed this primarily to increasing LAI. According to Watson (1958), the relationship of NAR to LAI is unlikely to be strictly linear, over the whole range of LAI. When LAI is less than unity, or does not much exceed it there should be little mutual shading of leaves and NAR should therefore not be much affected by change of LAI within this limit. As the plant becomes taller, self-shading is enhanced and there may be an exceedingly steep light gradient between the top and bottom of the plant. Spatial arrangement did not affect NAR possibly because there was not much difference in the degree of shading within the treatments due to the different spatial arrangements used.

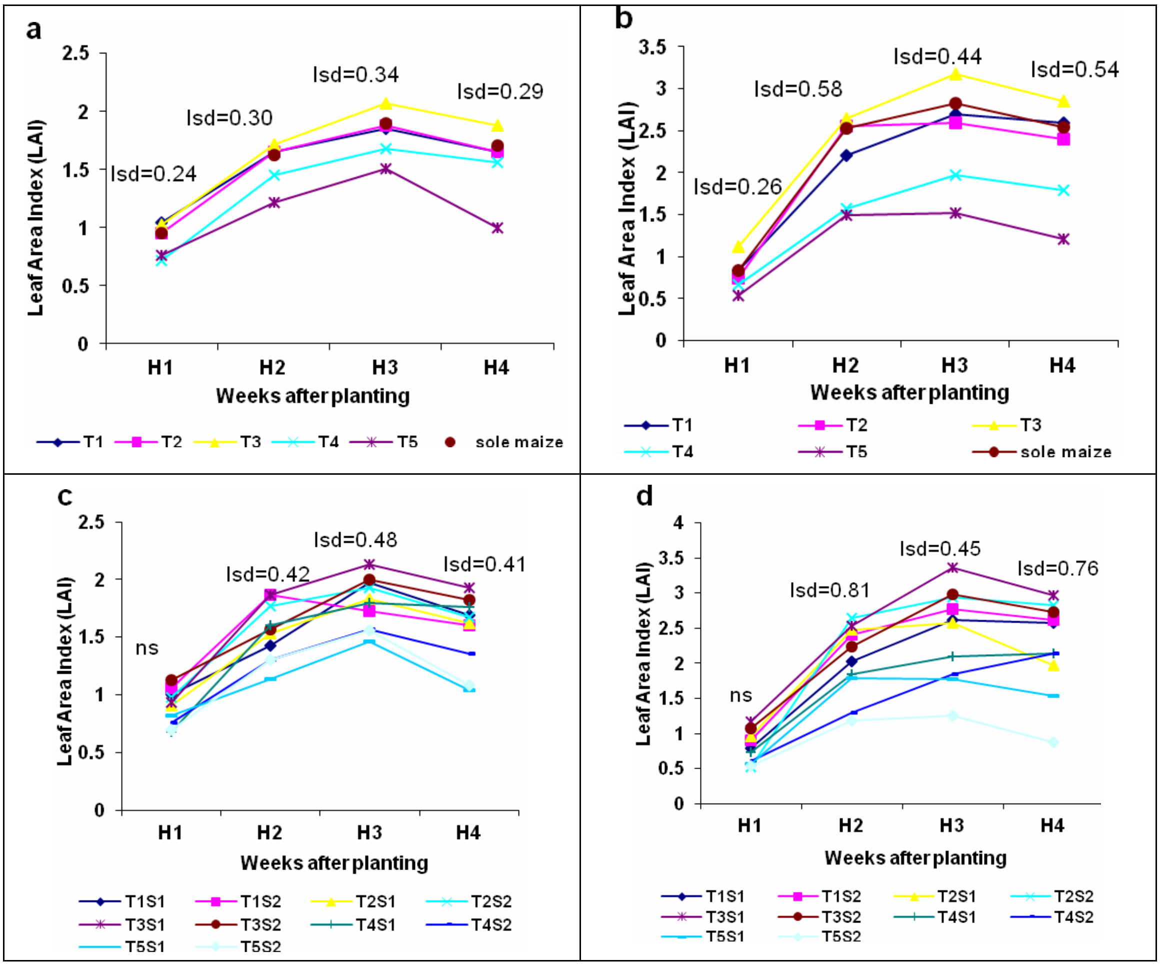

Figure-1. Effects of time of introduction of maize and soybean and spatial arrangement on leaf area index of maize. (a) Time of introduction effect in Experiment 1, (b) Time of introduction effect in Experiment 2, (c) Spatial arrangement effect in Experiment I, and (d) Spatial arrangement effect in Experiment 2.

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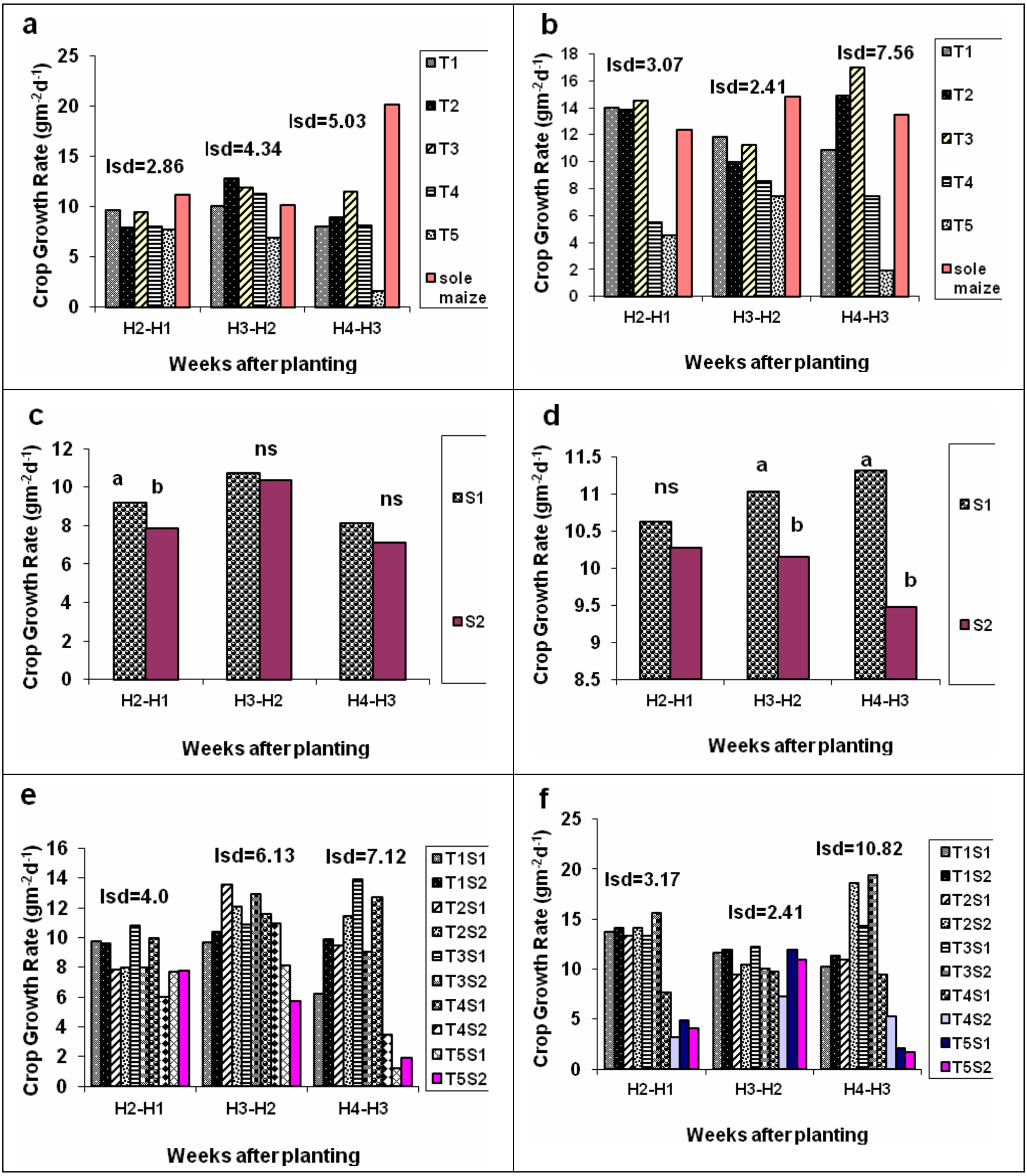

Figure-2. Effects of time of introduction of maize and soybean and spatial arrangement on crop growth rate of maize. (a) Time of introduction effect in Experiment 1, (b) Time of introduction effect in Experiment 2, (c) Spatial arrangement effect in Experiment 1, (d) Spatial arrangement effect in Experiment 2, (e) Time of introduction and spatial arrangement interaction effect in Experiment 1, and (f) Time of introduction and spatial arrangement interaction effect in Experiment 2.

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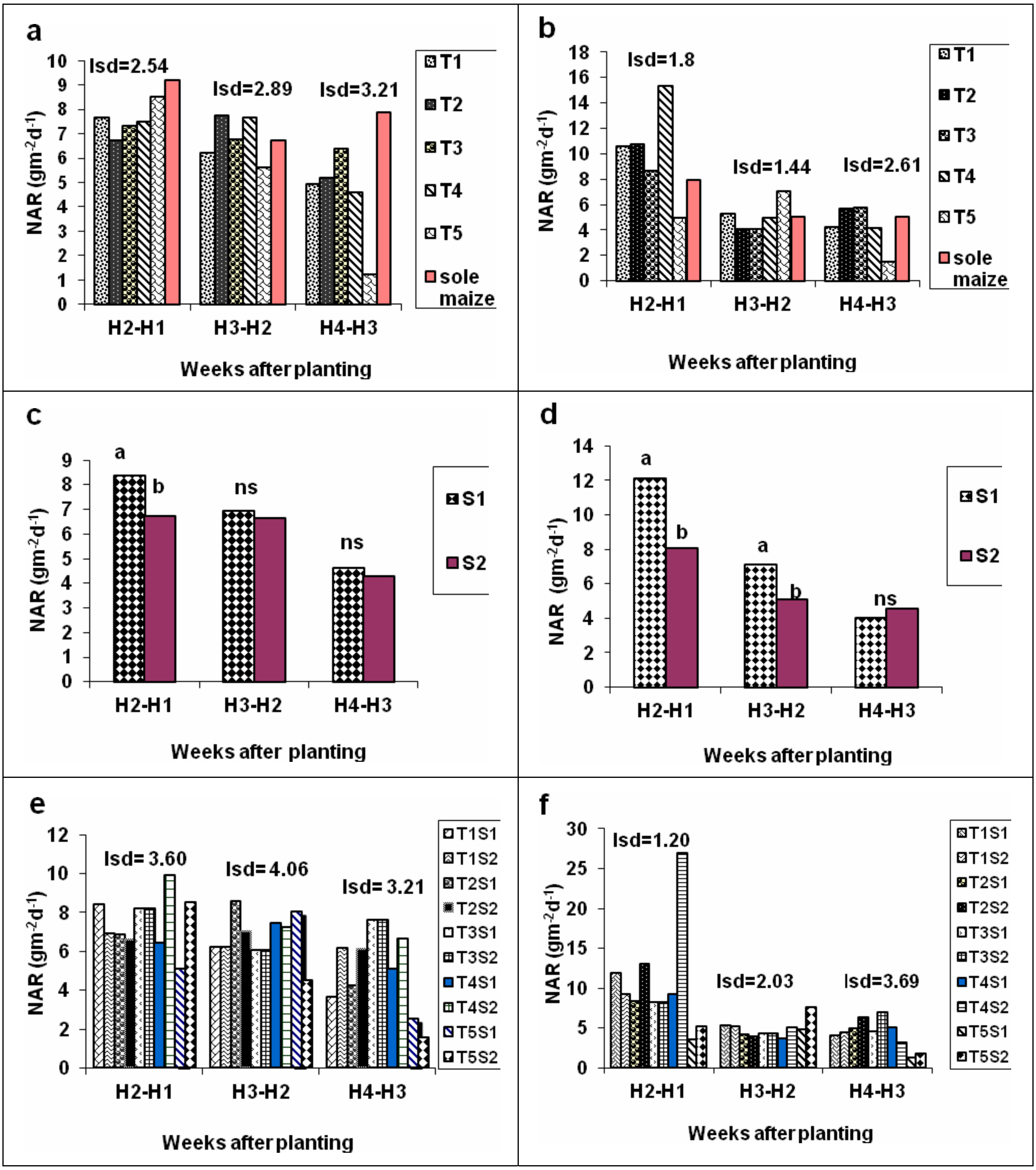

Figure-3. Effects of time of introduction of maize and soybean and spatial arrangement on Net Assimilation Rate (NAR) of maize. (a) Time of introduction effect in Experiment 1, (b) Time of introduction effect in Experiment 2, (c) Spatial arrangement effect in Experiment 1, (d) Spatial arrangement effect in Experiment 2, (e) Time of introduction and spatial arrangement interaction effect in Experiment 1, and (f) Time of introduction and spatial arrangement interaction effect in Experiment 2.

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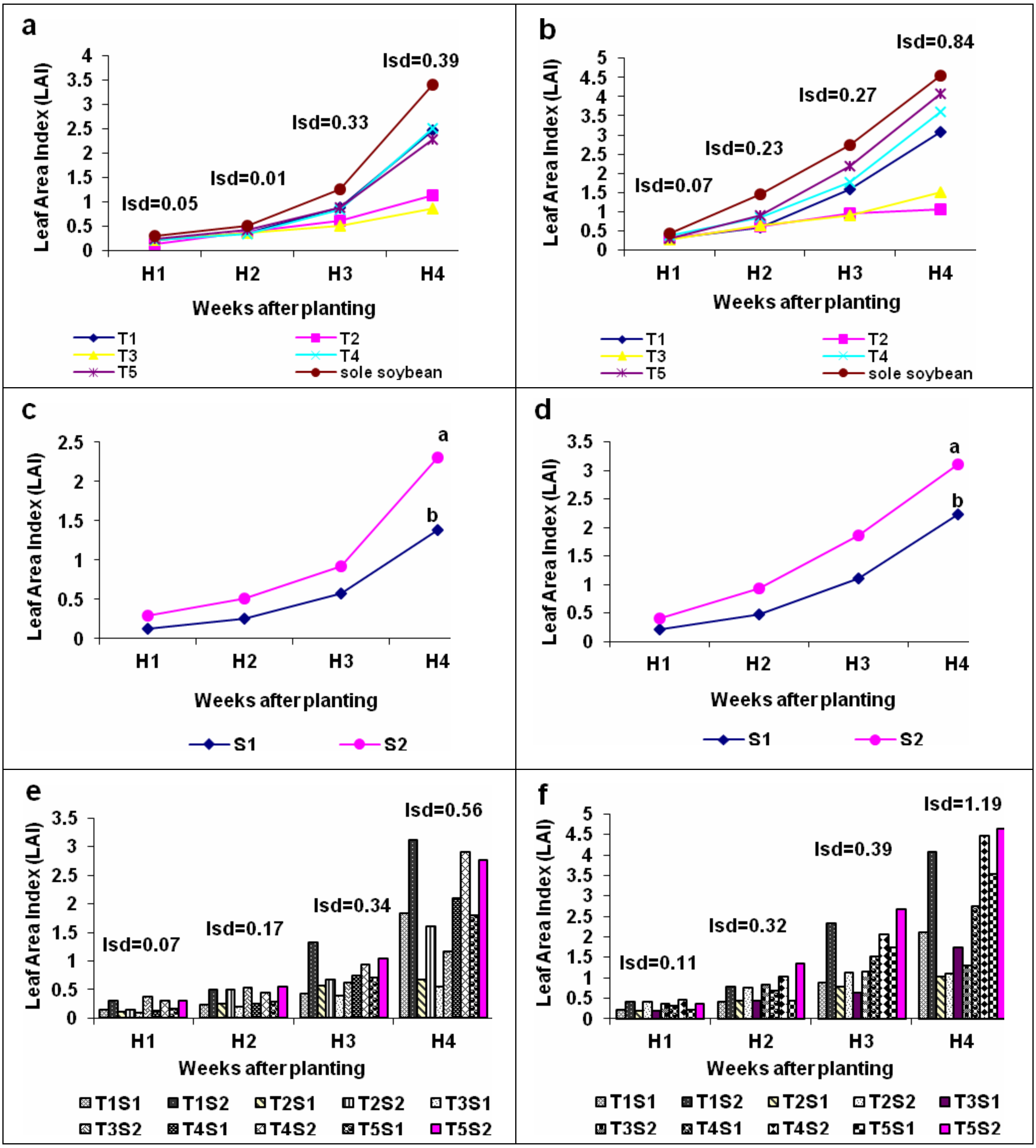

Figure-4. Effects of time of introduction of maize and soybean and spatial arrangement on leaf area index of soybean. (a) Time of introduction effect in Experiment 1, (b) Time of introduction effect in Experiment 2, (c) Spatial arrangement effect in Experiment I, (d) Spatial arrangement effect in Experiment 2, (e) Time of introduction and spatial arrangement interaction effect in Experiment 1, and (f) Time of introduction and spatial arrangement interaction effect in Experiment 2.

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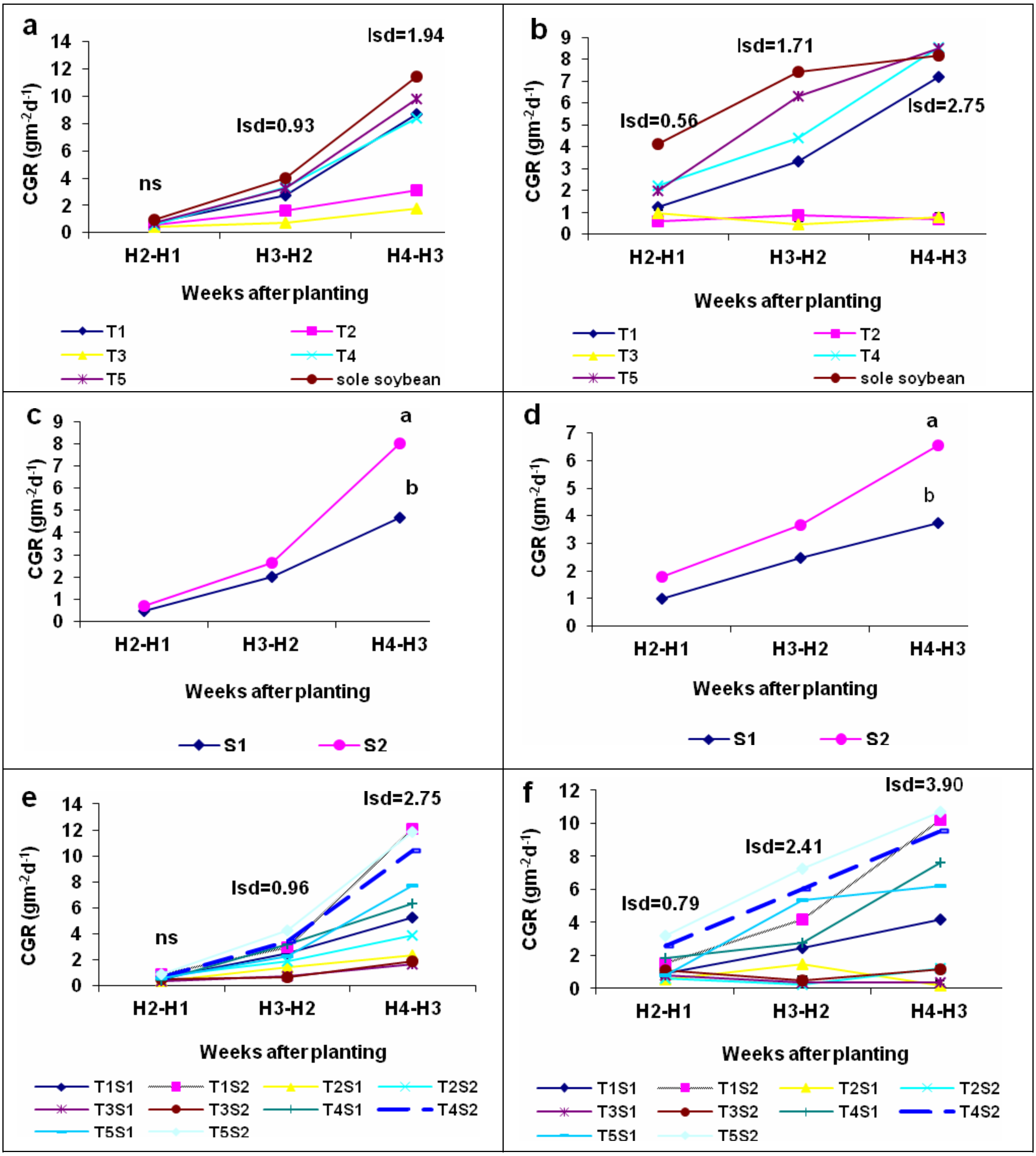

Figure-5. Effects of time of introduction of maize and soybean and spatial arrangement on crop growth rate of soybean. (a) Time of introduction effect in Experiment 1, (b) Time of introduction effect in Experiment 2, (c) Spatial arrangement effect in Experiment 1, (d) Spatial arrangement effect in Experiment 2, (e) Time of introduction and spatial arrangement interaction effect in Experiment 1, and (f) Time of introduction and spatial arrangement interaction effect in Experiment 2.

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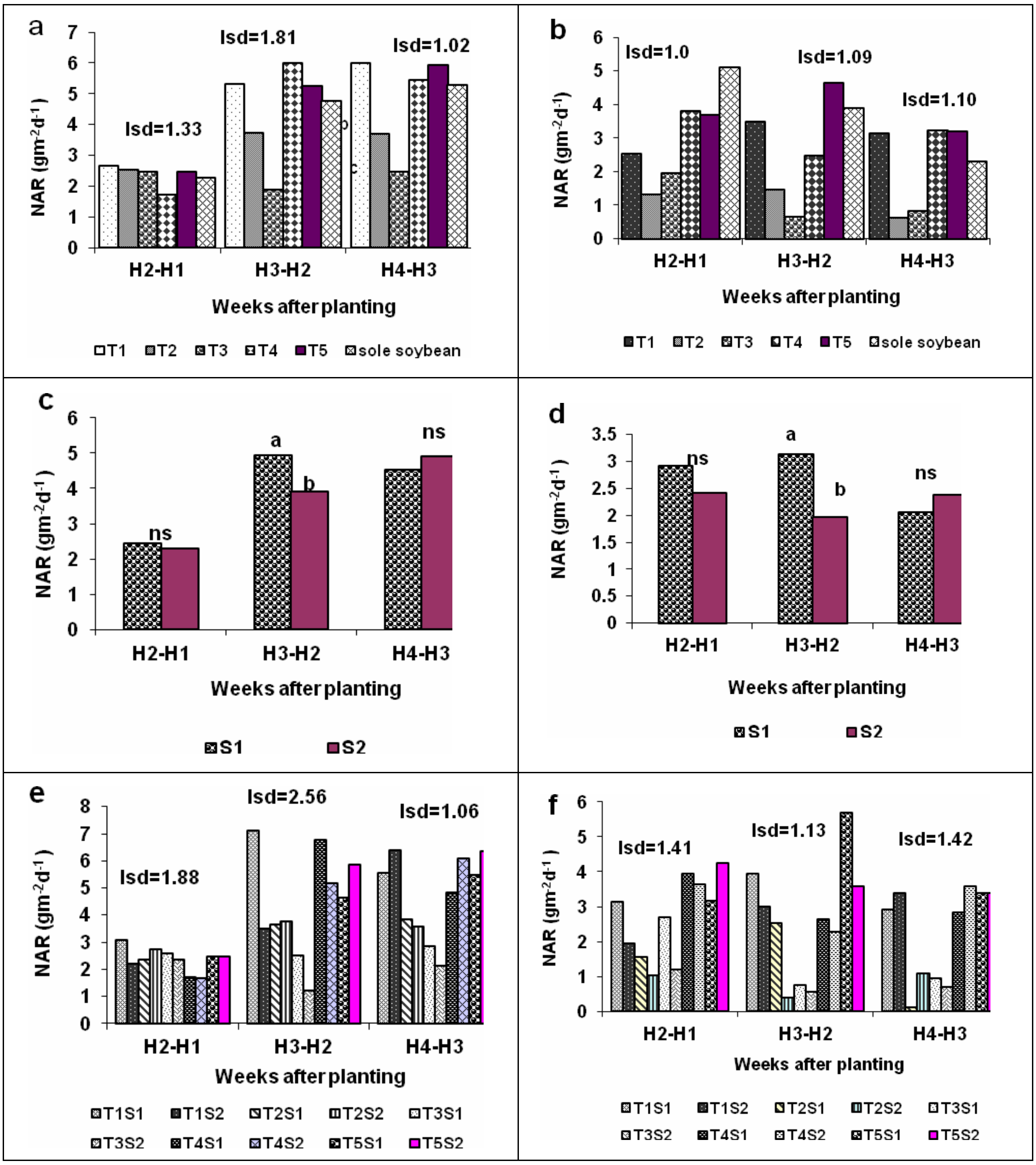

Figure-6. Effects of time of introduction of maize and soybean and spatial arrangement on Net Assimilation Rate (NAR) of soybean.
(a) Time of introduction effect in Experiment 1 (b) Time of introduction effect in Experiment 2, (c) Spatial arrangement effect in Experiment 1, (d) Spatial arrangement effect in Experiment 2, (e) Time of introduction and spatial arrangement interaction effect in Experiment 1 and (f) Time of introduction and spatial arrangement interaction effect in Experiment 2.

CONCLUSIONS

From the results the following conclusions can be drawn. The relative time of introduction of either maize or soybean into the intercropping system affected the LAI, CGR and NAR of both crops. When maize was planted simultaneously with or before soybean, growth of maize in terms of the measured parameters was higher than when it was planted after soybean. Similarly, the longer the introduction of maize into the intercropping system was delayed, the better the performance of the soybean crop.

The best result for maize was obtained for treatment T_3S_1, i.e., maize introduced 28 days before soybean. Similarly, soybean performed best when the introduction of maize was delayed by 28 days (T_5S_1).

Spatial arrangement did not significantly affect the growth of maize plants. In contrast, soybean growth was greatly affected. The LAI and CGR of soybean plants in double rows followed by single rows of maize arrangement were significantly higher than soybean plants in single rows alternating with single rows of maize. The NAR was however not affected by spatial arrangement. The effects of the treatments on yield and crop productivity will be examined in another paper.

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