STUDY OF THE SPECTRAL RESPONSE OF SOYBEANS

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Commission Number VII

ABSTRACT

The spectral responses of two soybeans varieties planted monthly (in a period of three months) and their relationship to percent ground cover, biomass and yield were investigated. Bidirectional reflectance factor was measured throughout the growing period (five campaigns at 20-day interval, approximately) of six experimental plots of 5 x 10 m size (three plots of each variety planted at one-month interval) using a 17 band (visible and NIR) portable radiometer. In each campaign, six measurements per plot were taken in order to obtain a representative estimate of the plot reflectance factor. Plant height and development stage were estimated concomitant to the radiometric measurements; biomass estimates were sampled three times per plot during specific development stages (flowering, grain filling, and maturation) and total plot production was measured at-harvest. The percent ground cover was estimated through photographs taken simultaneously to the radiometric measurements. Results indicated that differences in reflectance between the two varieties correspond to differences in their biomasses. However, in the visible peaked at 550nm there is a slight difference between the two varieties. Preliminary analysis of spectral trajectory plots and vegetation indices indicated that the reflectance measures are related to the studied agronomic variables.

1. INTRODUCTION

Soybean cultivation in Brazil experienced a great expansion through the last decade when the national production jumped from 1.5 (1970) to 15 million tons (1980) (EMBRAPA 1981) and for the crop year of 1987/88, 18 million tons are expected to be produced according to current official Brazilian government estimates. Although the majority of the area planted to soybeans (10 million hectares, approximately) is in the southern and central part of the country, there is a great potential to bring other lands into production specially in the north and northeast of Brazil (EMBRAPA 1981).

Among several factors that determined this tremendous increase in the soybean production in Brazil such as market, double cropping with wheat, government credit (production and commercialization), and the establishment of cooperative organizations, is the governmental support for research and technical assistance to the farmers. A good example is the establishment of the National Center for Soybean Research (CNPSo), located in Londrina, Paraná State as an EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria) unit.

As a result from this research effort, new varieties became available, specially to be planted in non-traditional soybean areas. This is the case of the two varieties considered in this study, which are being tested in the Paraiba Valley, which is a rice producing (15,000 ha of irrigated rice - Miyasaka and Medina, 1981) and a livestock area.

These varieties were introduced in this region to provide alternatives for cattle feeding during the dry winter season and also for green manure to be incorporated into the soil as a rotating crop for the rice production areas keeping them free of weeds during the winter time. These varieties are also being tested for grain production at the Experimental Station of Pindamonhangaba, SP, from the São Paulo government. They were selected among several other varieties since 1956 because they are tolerant to photoperiodism, low temperature, soil acidity, and excessive soil moisture, typical of the Paraiba Valley soils (Miyasaka and Medina, 1981).

Several papers have reported conclusively that spectral data are significantly correlated with photosynthetically active portion of the crop canopy (e.g. Boutton and Tieszen, 1983; Holben et al., 1980; Daughtry et al., 1984; Kollenkark et al., 1981; Blad et al., 1985).

Crist (1982) analyzing very large data sets from field spectroscopy studies has established the normal spectral profile for soybean spectral response. However, several factors, may determine deviations from that normal profile, one of them being the planting date (early or late planting). Therefore, it remains important to investigate the spectral behavior of soybeans planted during the winter growing season in a tropical environment.

This paper reports on an experiment in which spectral information obtained throughout the growing cycle of two varieties of soybeans planted at different dates during the winter time was investigated and derived vegetation indices were correlated with total fresh biomass, plant height, percent soil cover, and grain yield.

2. EXPERIMENTAL PROCEDURE

This experiment was conducted at the Hydro-agricultural Research Center - Eng. A. G. Borba from the DAEE (Departamento de Águas e Energia Êletrica de São Paulo), located at Pindamonhangaba, São Paulo (22º54' S and 45º25' N).

Six plots corresponding to three planting dates (one month interval) of two varieties (IAC-9 and Santa Maria - SM) were investigated. The plots were 10 x 5 m with 0.5 m of row spacing, 25 seeds/m (manually planted) with 10 rows per plot on a flat clayey soil (BT) which was fertilized before planting. Water, weeding, and preventive pest control were supplied as needed throughout the growing cycle and all biotic and abiotic events were registered.

Six spectral measurements (three centered on the row and three between rows) per plot were obtained five times with 20 day -

intervals, approximately, throughout the growing cycle with a hand - held nadir pointing portable radiometer with 17 spectral bands from 400 nm to 1050 nm. Measurements were taken between 10:40 and 13:50 in clear sky conditions. Only occasionally, smoke from a nearby small plant appeared on the sky but care was taken to avoid its interference. The radiometer with an IFOV of 10^o was held at 3 m above the crop canopy. A reference reading was taken from a $BaSO_4$ panel prior and after each on the crop spectral measurement. The procedure used for the spectral data collecting followed recommendations from Biehl and Robinson (1983) and procedure used by Holben et al. (1980).

Simultaneously with the spectral measurement a 35 mm photograph was taken for percent soil cover estimate as suggested by Cihlar et al. (1987). Plant height was obtained close to the radiometric measurements based on the mean of 10 plants per plot, per date. Total fresh biomass was taken three times per plot during beginning of flowering, grain filling, and maturation,and therefore not necessarily coincident with the radiometric measurements. Two meters of one row (1 m^2) were randomly selected, cut and immediately weighted per plot, per biomass estimate. The grain yield was estimated by total plot harvesting (47 m^2).

3. RESULTS AND DISCUSSION

Before making the crop reflectance analyses, the performance of the portable radiometer was checked. It was hypothesized firstly that there was no change on the reflectance property of the reference panel throughout the measurement campaigns, and secondly that the sky was constantly clear (no atmospheric interference changes), therefore any change on the radiance readings from the reference panel was due to solar radiation and or due to instability of the radiometer. Since the solar radiation changes are quite predictable, the radiometer performance could be assessed under the assumptions made. It can be noticed on the figure 1 that the panel response is quite smooth throughout the measuring period. In fact, the largest variation occurred on September 15, when the difference between the largest radiance reading (at 10:45) and the lowest (at 13:15) was around 10% for the 550 nm and 8% for 850 nm wavelengths following the variation on the sun-target geometry. The largest spurious variation were around 2% for the two wavelengths analyzed. Therefore, for those clear sky conditions we could have spaced more the measurements of the reference panels without compromising data quality.

Figure 2 shows the seasonal variation on the spectral response of the two varieties planted at three different dates (May 15, June 19 and July 15). The spectral curves follow very closely the pattern presented by Bowker et al. (1985).

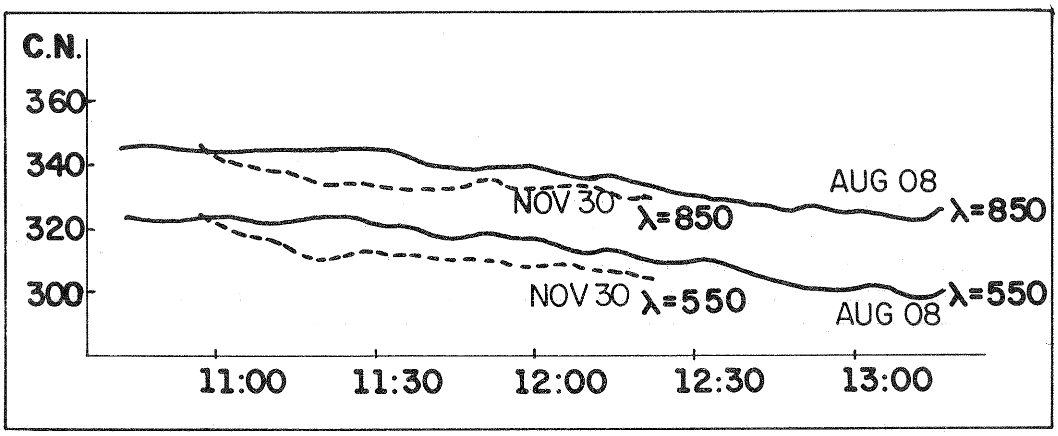

Fig.1 - Radiance measurements of the $BaSO_4$ reference panel for the two extreme dates.

Figure 3 shows the seasonal spectral profile of the six analyzed plots based on the ratio vegetation index (ratio of the near infrared band centered at 850 nm and the chlorophyll absorption band centered at 650 nm). It can be noticed that the Santa Maria variety senesces earlier than the IAC-9 (plot 1 vs 2 and 3 vs 4). Despite of only few measurements taken throughout the growing cycle, the asymmetry of the soybean variability about the mean described by Crist (1982) is noticeable on the profile of plots 1, 2 and 4 (Figure 3).

Figure 4 shows in a comparative way the spectral trajectory of the soybean varieties studied. Plots 5 and 6, planted later, presented the greatest variation on both visible and near infrared reflectance factors.

Figure 5 shows that spectrally the two varieties studied are very similar. However, in the visible band, at the peak of green reflectance (550 nm), the Santa Maria variety has a slightly greater reflectance than the IAC-9, except for the September 15 observation on plots 5 and 6, which were planted on July 15 and had lower than 20 percent soil cover.

Figure 6 shows that ratio vegetation index is quite well correlated with all agronomic variables studied. The correlation with fresh biomass was exceptionally high, especially considering that the spectral measurements were not taken at the same date of the biomass estimates. This is very encouraging considering that these varieties are planted with the primarily objective of biomass production.

In spite of the fact that these varieties were planted during the winter time, the results were quite comparable to other previous findings (e.g. results reported by Perry and Lautenschlager (1984), Holben et al. (1980); Daughtry et al. (1984); Kollenkark et al. (1981)).

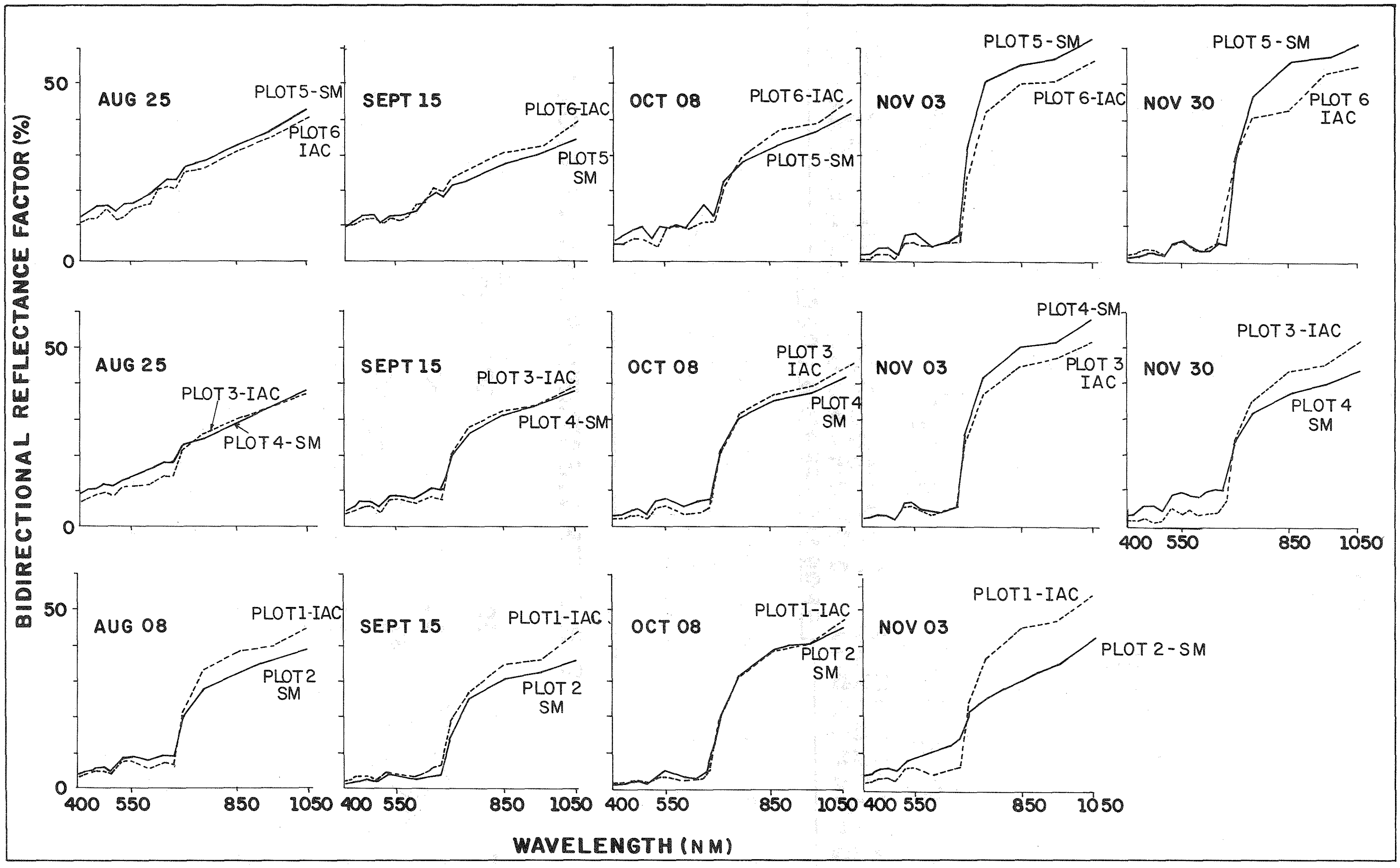

Fig. 2 - Average spectral reflectance of the six plots, on five dates of two soybean varieties (IAC-9 and Santa Maria-SM).

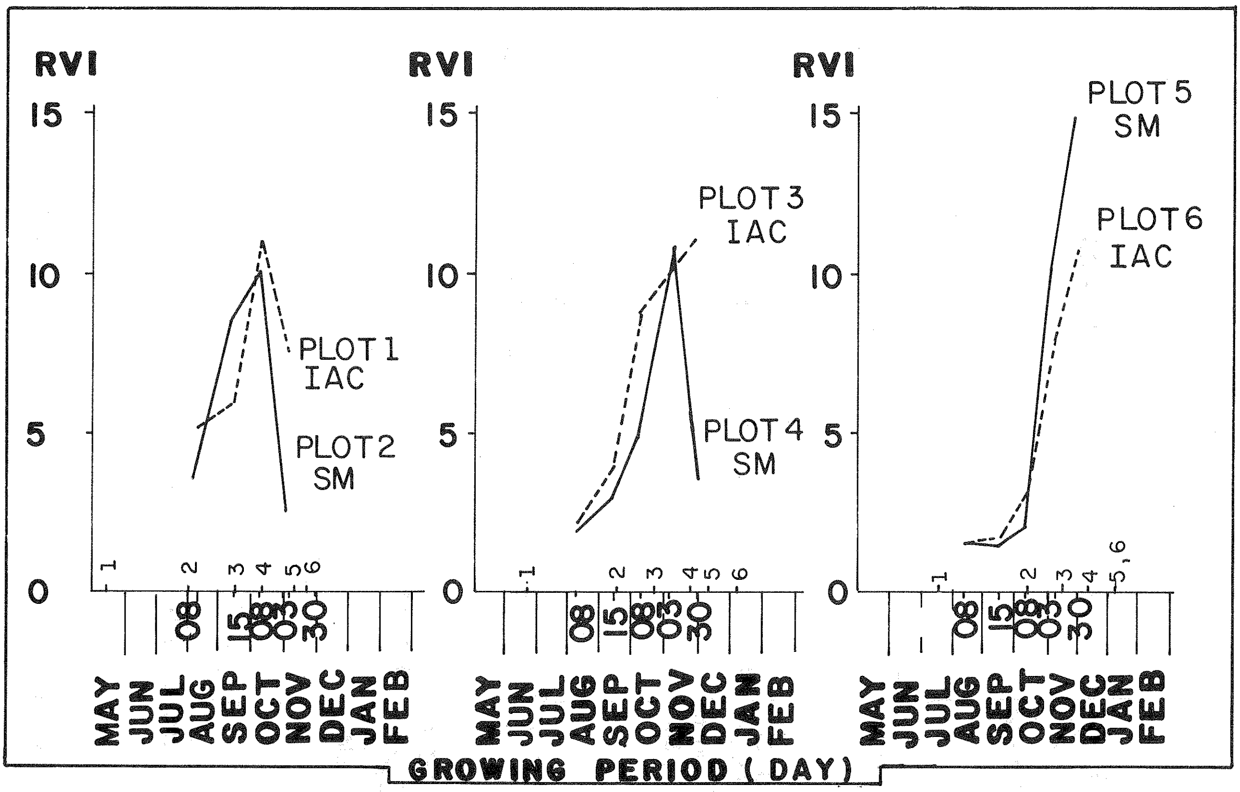

Fig. 3 - Seasonal change in the ratio vegetation index (RVI) of soybeans (1= planting, 2= flowering, 3= grain filling, 4= maturation, 5= harvesting of SM variety, 6= harvesting of IAC-9 variety).

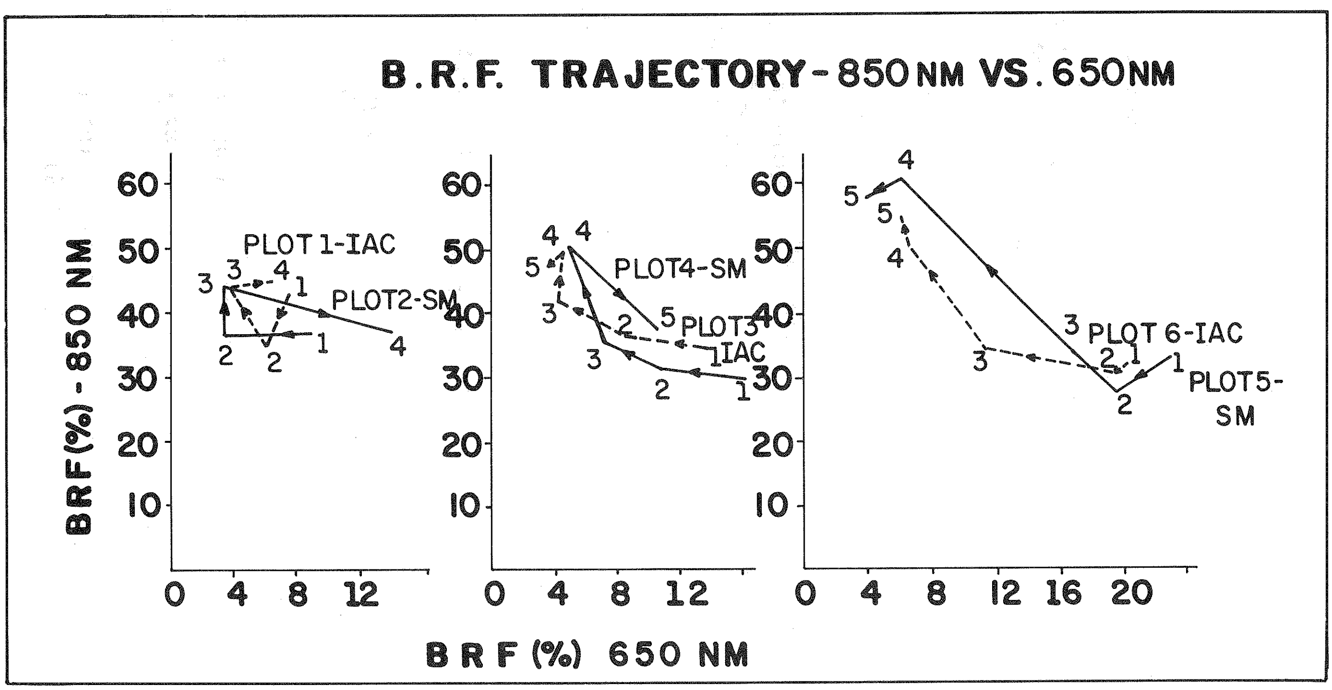

Fig. 4 - Seasonal spectral trajectory of two soybean varieties (1- Aug 8, 2- Sept 15, 3- Oct 8, 4- Nov 3, 5- Nov 30, 1987).

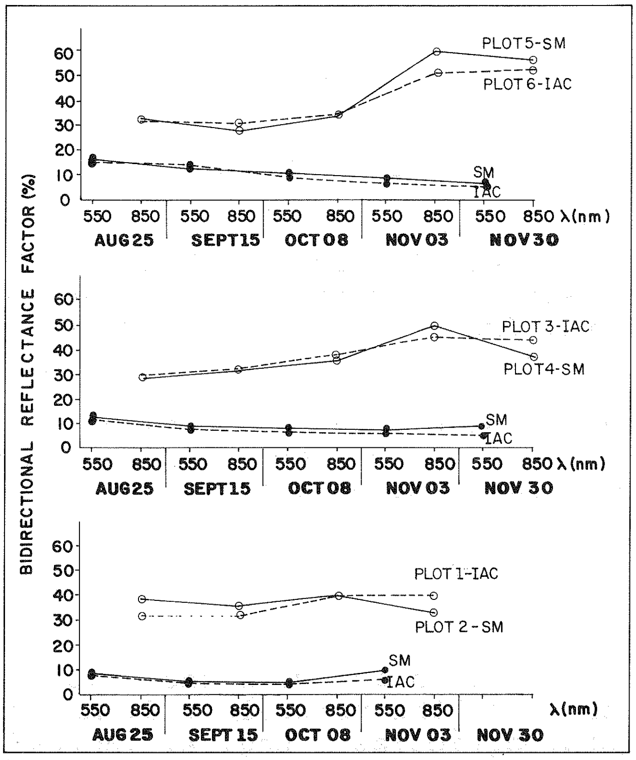

Fig. 5 - Seasonal variation on soybean reflectance factor at two spectral bands, centered at 550 nm and 850 nm.

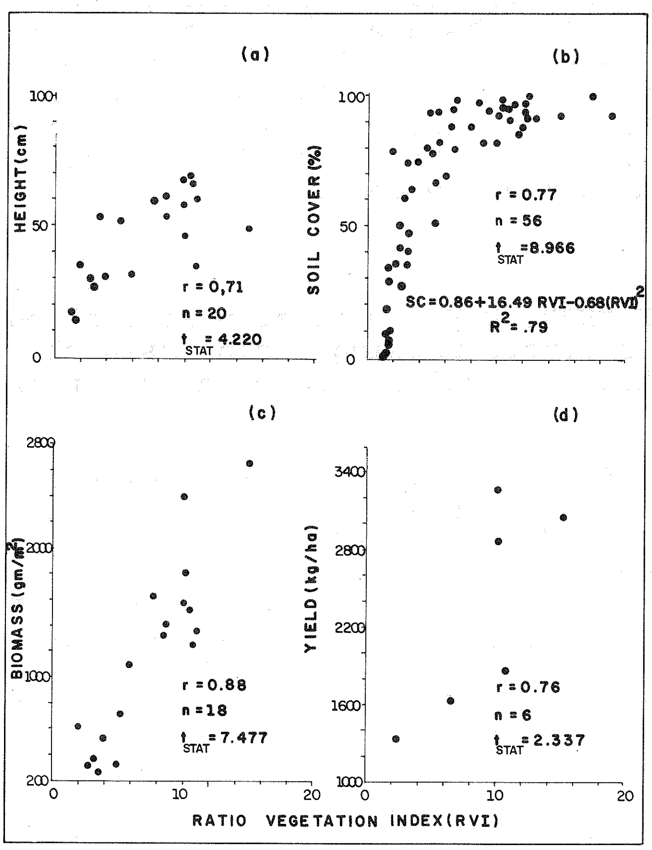

Fig. 6 - Relationship between the ratio vegetation index (RVI) and agronomic variables (a- plant height, b- percent soil cover, c- total fresh biomass, d- grain yield).

4. CONCLUSIONS

In spite of the studied varieties of soybeans to have been selected for biomass production during the winter growing season, their spectral response in the visible and near infrared are very similar to the pattern of soybean reflectance reported on previous researches.

The ratio vegetation index (RVI) (near infrared/red) was highly positively correlated with all agronomic variables studied (plant height, percent soil cover, total fresh biomass, and grain yield). The RVI explained 78 percent of the variation in biomass. This result is particularly relevant considering that these two measurements were not taken at the same date. Conventional biomass estimates at the field level can be very time-consuming, therefore, spectral measurements might be an alternative method for reliable biomass estimate of soybeans for the Paraiba Valley in Brazil.

5. ACKNOWLEDGEMENTS

This experiment was conducted in cooperation with the "Instituto Florestal de São Paulo" that provided the portable radiometer and with the "Campo de Pesquisas Hidroagrícolas - Eng. A.G.Borba" from the Departamento de Águas e Energia Elétrica de São Paulo (DAEE)" that provided the facilities and support for the field experiment. Special thanks are due to Mr. Norberto Leite and Mr. Hideyo Aoki, senior researchers from the DAEE experimental station and from the "Instituto Florestal de São Paulo", respectively. The authors wish also to express their gratitude to Dr. Raimundo A. Filho and Mr. Carlos A. Steffen for their help on the field spectral data measurements.

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