REPORTS & NOTES

HortScience 15(2):138–140. 1980.

The Effect of Rice-hull Mulch on Growth, Carbohydrate Content, and Nitrogen Fixation in *Phaseolus vulgaris* L.[1]

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Additional index words. bean, soil temperature, soil moisture, tropics

Abstract. **Mulching 'Puebla 152' beans with rice hulls to a depth of 4 cm reduced afternoon soil temperature, soil temperature fluctuation, and slowed the loss of soil moisture. These effects were greatest prior to canopy closure. Fresh weight of nodules, roots, stems, leaves, and total plant increased 50%, 38%, 49%, 24%, and 38%, respectively, with mulching, but pod and final seed weight were unaffected. Mulching had little effect on the concentration of soluble and insoluble carbohydrates. N_2 fixation rates (C_2H_2 reduction) were low ($\leqslant$ 0.6 µmole/plant per hr) but were as much as 3 times higher in mulched than unmulched plants.**

Growth and production of beans in hot tropical regions appear to be restricted by high soil temperatures which enhance respirational losses and reduce the availability of carbohydrate (7). Satisfactory nodulation and N_2 fixation, which require an adequate supply of carbohydrates (8, 11), are rarely obtained in these regions. Mulches have been widely used to lower soil temperatures and to retain moisture, and have promoted both bean yield (2, 10) and nodulation (9). Nodulation of cowpeas has also been increased when soil temperatures were lowered with a straw mulch (12).

Rice hulls are readily available in many tropical regions and could be used as mulch to improve temperature and moisture conditions in the soil. The effect of rice-hull mulch on growth, N_2 fixation, and carbohydrate levels of beans was investigated at the Centro Internacional de Agricultura Tropical (CIAT) in Palmira, Colombia.

'Puebla 152' (CIAT designation P498) bean, capable of relatively high rates of N_2 fixation at highland tropical locations (6), was grown on a heavy clay soil supplemented with commercial fertilizers. No nitrogen was applied. Seeds were surface sterilized with calcium hypochlorite, inoculated with *Rhizobium phaseoli* (CIAT strain 57), lime pelleted and then planted in rows 50 cm apart. Seedlings were thinned to 10 per m within rows and a 4 cm cover of rice hulls applied when primary leaves were fully expanded. Mulched and unmulched control plots were arranged in a randomized complete block design with 5 replications. Sprinkler irrigation was applied at planting, mulching, and when soil moisture dropped below 15% in the mulched plot.

Soil temperature at 10 cm below the soil surface was monitored at 2:30 PM 3 times weekly. Similarly, 3 in-row samples from the top 10 cm of soil were taken at random in each plot and combined for soil moisture determination.

Plants were harvested from bordered positions in each plot at 21, 35, 51, and 61 days after planting and at dry pod maturity on day 89. Twenty plants were harvested per replicate but only the 10 plants most representative of the plot were used. After carefully removing adhering soil, plants were divided into nodulated root system, stem, leaves, and pods when present. N_2 fixation of each nodulated root system was estimated by acetylene reduction as described by Graham and Rosas (6). Roots and nodules were then separated. Plant parts were weighed and 15g of fresh tissue immersed in 70% ethanol. Ethanol soluble and insoluble (perchloric acid extractable) carbohydrates were determined with anthrone (6, 7).

Mulching reduced soil temperatures at 10 cm and improved soil moisture content, the differences being greatest prior to canopy closure and flowering (Fig. 1). Thus, prior to bloom, mulching lowered the afternoon soil temperature an average of 1.3°C and increased soil moisture 2.2%. Corresponding figures after bloom were 0.8° and 0.6%, respectively. Diurnal fluctuation in soil temperature was also reduced by mulching. For 5 days during mid pod-fill the mean difference between

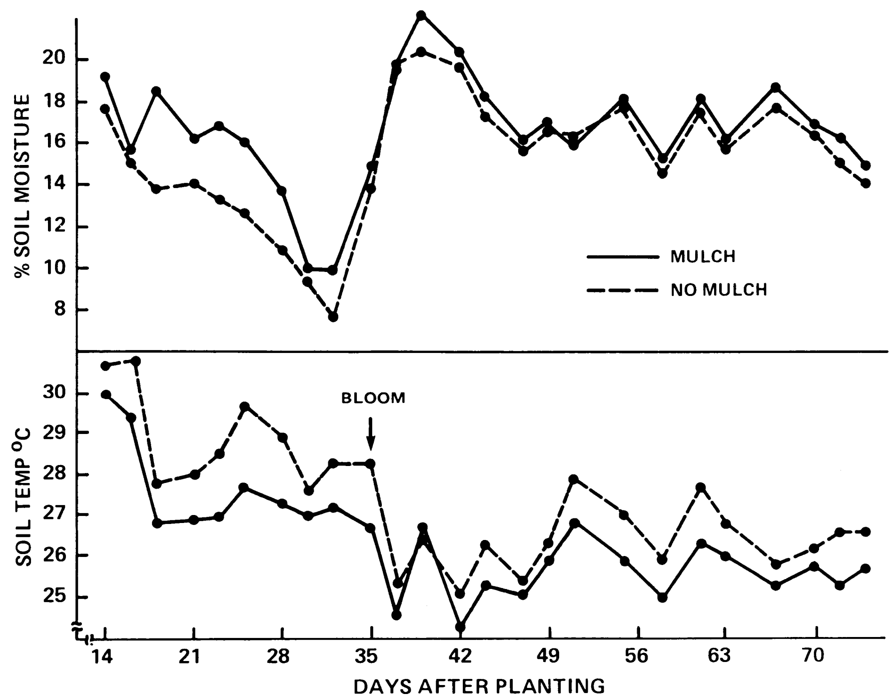

Fig. 1. The effect of rice hull mulch in beans on soil temperatures at 10 cm depth and soil moisture content in the top 10 cm soil.

[1]Recieved for publication October 3, 1979. Oregon Agricultural Experiment Station Tech. Paper No. 5304. From the PhD dissertation of the senior author.

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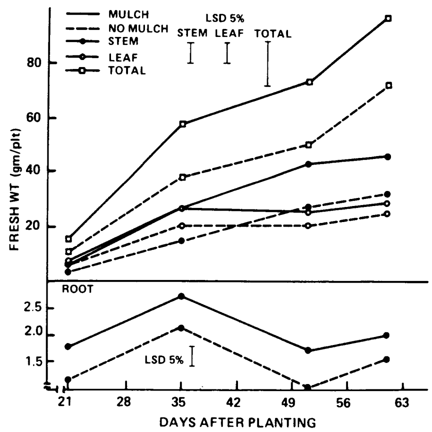

Fig. 2. The effect of rice hull mulch on fresh weight of bean plant parts.

Table 1. Concentration of soluble, insoluble, and total nonstructural carbohydrates in roots, stems, and leaves of bean at 35, 51, and 61 days after planting.

Plant part	Carbohydrate fraction	% of residue dry wt			
		35	51	61	LSD 5%
Root	Soluble	2.38	2.08	2.04	ns
	Insoluble	3.91	6.94	9.72	1.56
	Total	6.29	9.02	11.76	1.28
Stem	Soluble	4.41	3.28	3.60	ns
	Insoluble	5.55	7.87	13.68	3.10
	Total	9.96	11.15	17.28	2.85
Leaf	Soluble	3.40	2.51	2.38	0.75
	Insoluble	4.47	3.81	4.89	ns
	Total	7.87	6.32	7.26	ns

early morning (6:30 AM) and afternoon soil temperatures at 5 cm and 10 cm were, respectively, 3.8° and 2.3° in mulched plots and 5.3° and 3.6° in unmulched plots.

Mulching increased root, stem, leaf, and total plant fresh weight by 38%, 49%, 24%, and 38%, respectively (Fig. 2), but did not influence pod or final seed weight, which was 114 g/m^2. Difference between treatments in the weight of plant parts was established during vegetative growth, when the mulch was most effective, and maintained during the remainder of the season. The failure of mulch to influence seed yield may be related to its limited effect on soil temperature and moisture during reproductive development. Yields usually are not improved by mulching to the extent that vegetative growth is increased (10).

The total amounts of nonstructural carbohydrates in all plant parts were higher in the mulch treatment, but only the increases in roots (37%) and leaves (42%) were significant (data not shown). This increase was due to the greater weight of plant parts from mulched plots since mulching had no effect on the concentration of total, soluble, and insoluble carbohydrates and the data were combined for stage of development (Table 1).

The seasonal increase in the concentration of total carbohydrates in both the root and stem resulted from a rise in the concentration of ethanol insoluble carbohydrates (Table 1). The concentration of soluble carbohydrates remained unchanged. The accumulation of the insoluble fraction during pod-fill is consistent with other findings (1, 5, 6) indicating either excess photosynthetic capacity or inefficiency in mobilizing reserves.

Levels of N_2 (C_2H_2) fixation and nodulation were low (Fig. 3) when compared with other data for this cultivar (6) but are similar to values recorded previously at this lowland site (Graham, unpublished). Significant increases were obtained in response to mulch. Since rice hulls are decomposed relatively slowly, this is unlikely due to nitrogen immobilization or solubilization of limiting elements. The N_2 (C_2H_2) fixation rate of mulched plants was 3 times that of unmulched plants at full bloom (day 35), and at early pod-fill (day 51) was still more than double the unmulched. Nodule weight, which at bloom was 50% higher in mulched than control plants (Fig. 3), was positively correlated (r = 0.80) with N_2 (C_2H_2) fixation. Mulching did not affect specific nodule activity.

Highest afternoon soil temperatures and largest difference between mulched and unmulched plots occurred prior to bloom when nodule development was most active. Even during this period, however, the soil temperatures at 10 cm rarely exceeded 29°C, which Small et al. (13) found optimum for nodulation but inhibitory to nitrogen accumulation in inoculated bean plants. At depths of less than 10 cm, soil temperatures in excess of this value could have been expected more frequently in unmulched than mulched plots. Temperatures at 5 cm in adjacent uncropped soil were frequently in excess of 35°C. While the same

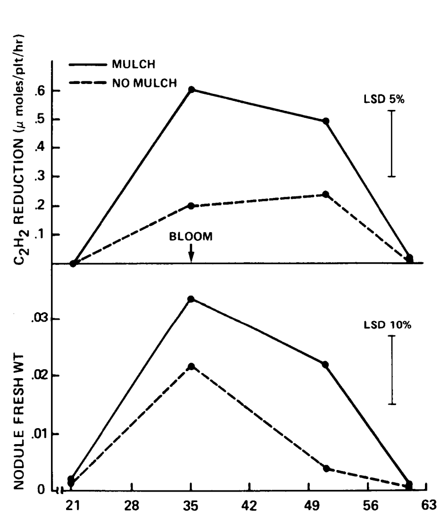

Fig. 3. The effect of rice hull mulch on nodule fresh weight and N_2 (C_2H_2) fixation in beans.

bean cultivar used in this study is capable of high rates of N_2 fixation at temperatures as high as 35° (4), recent studies suggest that the *Rhizobium* strain CIAT 57 is affected in symbiotic capability by such temperatures (3).

The higher soil moisture level in mulched plants during the first 2.5 weeks after mulch application (Fig. 1) was likely beneficial to both nodulation and N_2 fixation. Sprent (14) reported a close relationship between soil moisture and N_2 (C_2H_2) fixation with several legume crops. She also found that withholding water from bean plants until wilting greatly reduced nodule number, size, and acetylene reduction activity. Further experiments are needed to determine the extent to which plant water stress, as well as soil factors, contribute to the observed poor N_2 fixation of beans in the lowland tropics.

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HortScience 15(2):140-141. 1980.

Improving the Heat Unit System in Predicting Maturity Date of Snap Beans[1]

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Additional index words. growing degree days, heat units, soil moisture

Abstract. **Field experiments were conducted at Clemson University in 1975, 1976, 1977, and 1978 to study the accuracy of the heat unit system in predicting maturity date of snap beans. The growing-degree day method was found to be unreliable. Indications were that other environmental factors, in addition to temperature, affected the maturity of this crop. The available soil moisture for each of 10 plantings grown under natural rainfall varied greatly. Because of the unreliability of the heat unit method, it was decided to integrate the available soil moisture parameter into the degree day method. The formula that gave the smallest coefficient of variation was one using the daily heat unit multiplied by a ratio of the available soil moisture to a constant soil moisture value. Predicting the maturity of snap beans was improved by integrating available soil moisture into the heat unit system.**

Snap beans must be harvested at a specific stage of maturity to obtain the highest quality (8). Most cultivars become tough and fibrous if left on the plants beyond their optimum stage of quality. Accurately predicting, in advance, the maturity date of a particular field of beans is of the utmost importance to growers, farm managers, and processing plant supervisors. Labor requirements and processing operations are scheduled according to this predicted date. The method most often used by processors in predicting harvest date is the heat unit system in which daily mean temperature above a certain threshold temperature are accumulated from the day of planting until the plant matures.

The summation of temperature as an indicator of plant growth and development was introduced by the French physicist, R. A. de Reamur in 1735. Since that time, the heat unit system has found widespread use, especially in the vegetable processing industry (2, 4, 16). Abbe (1) pointed out that, according to the doctrine of thermal constants, a given stage in the development of a plant is reached when that plant has received a certain amount of heat, regardless of the length of time required. Nuttonson (14) reported that this heat requirement was given a mathematical expression commonly called "heat units." The unit was a degree on one of several thermometer scales.

Boswell (5) using summations above base 40°F, found that a fairly constant amount of heat was needed to reach blooming stage of garden peas, regardless of the time interval. Gould (6) using 50°F as the base temperature, studied 47 cultivars of snap beans and found that on the average, snap beans require 27,000 degree hours to reach optimum stage of maturity.

In spite of many applications and intensive investigations over two centuries, the heat unit system has been subjected to serious criticism, particularly in recent years (7, 12, 13). Even its faithful users in the canning industry have found flaws in the system and are seeking means of improvement. One of the disadvantages of the heat system, according to Wang (21), is that it does not take into account many factors which influence plant growth and development, such as soil moisture, vapor pressure deficit, precipitation, solar radiation, and other meteorological elements. It has long been recognized that during periods of soil moisture stress, soil moisture acts as a limiting factor on the growth and development of a plant. Richards and Wadleigh (18) reported that the growth of a plant decreases progressively as the soil moisture stress increases. Singh and Alderfer (19) found that a shortage of water during the early growth of snap beans reduces plant growth. Kattan and Fleming (9) reported that yield and quality of snap beans are affected most if a high moisture stress develops during flowering and pod development. Reynolds (17) found that the highest yields of snap beans were obtained when the available soil moisture was maintained above 50%. Bradley (3) reported that the yields of snap beans declined linearly with a decrease in the soil moisture level.

In 1966, a method was devised that improved the accuracy of the heat unit system (11). Available soil moisture was integrated into the heat unit formula. The method is called soil moisture growing-degree days (SMGDD). Application of this new method to 10 plantings of 'Blue Lake 274' snap beans is described in this report.

Ten plantings of 'Blue Lake 274' were made in 1975, 1976, 1977, and 1978 in a Buncombe sandy loam at Clemson, South Carolina. The water holding capacity in the top 30 cm is 3.56 cm. Each crop was hand-harvested when 50% of the pods attained sieve size 5 and larger (20). A continuous recording hygrothermograph, located at the site, was used to obtain temperature data. The temperature sensing element was located 30 cm above the ground surface and housed in an official National Weather Service instrument shelter. A recording rain guage was used to obtain the precipitation data. The observation day was for a 24-hour period ending at 8 AM. Soil moisture in the upper 30 cm of the soil was computed daily using the Palmer and Havens (15) modification of the Thornthwaite method as adopted to South Carolina soils by Kish (10).

Growing-Degree Days. To compute growing-degree days (GDD) for a 24-hr period, the maximum and minimum temperatures are added then

[1]Received for publication May 3, 1979. Technical Contribution No. 1680 South Carolina Agricultural Experiment Station. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.
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