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THE INFLUENCE OF PHYSICAL ENVIRONMENTAL FACTORS ON THE PRODUCTIVITY POTENTIAL OF FABABEANS.

by

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ABSTRACT.

Evaluation of the influence of soil physical and agroclimatic variables on fababean production indicates that accumulated soil and atmospheric heat, evapotranspiration and soil moisture supply are critical factors in determining seed and silage yields. Satisfactory yields are only obtained when the soil moisture supply in the upper portion of the profile is adequate and when the level of accumulated soil heat at 20 cm depth exceeds the atmospheric heat accumulation by approximately 100 units. Growth on the main stem ceases after the receipt of between 1000 and 1150 soil heat units, the total within these limits being dependent upon soil moisture supply in the upper portion of the soil profile. Fababean production in Manitoba should not be limited by environmental factors in areas recieving less than 1550 atmospheric heat units between May 1st and September 30th and possessing a soil water deficit on September 30th of less than 20 cm.

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I INTRODUCTION

In 1974 the Department of Soil Science participated in a multidisciplinary project which was initiated to review the agricultural potential of the high protein seed legume Vicia faba L.

The responsibility designated to this particular portion of the project was an examination of the influence of the physical environment on the growth performance of this crop. This involved field, growth chamber and laboratory studies in which an attempt was made to quantify the individual and combined effects of agroclimatic and soil physical variables on crop development and yield productivity.

When this analysis was complete it was hoped that the relationships developed would allow prediction of which climatic areas in the Province would be most suitable for large scale field production of fababean seed and silage.

II REVIEW OF PREVIOUS RESEARCH

Seasonal Supply of Moisture

An adequate soil moisture supply is a critical requirement for successful legume growth (Salter and Goode, 1967). The level that can be regarded as adequate is dependent upon the ability of a crop to extract water under the tension at which it is being held in the soil. This moisture is required to maintain sufficient cell turgor to allow plant processes such as photosynthesis to occur unimpeded and also to provide a root environment suitable for a high rate of nitrogen fixation by the nodulating bacteria (Kuo and Boersma, 1971). If an adequate moisture supply is not maintained throughout the growing season this will be reflected in reduced plant growth performance, particularly in the case of Vicia faba minor which is a crop very sensitive to drought because its ability to utilize soil moisture reserves is limited (Listowski et al., after Gliemmeroth, 1952).

Field experimental results of El Nadi (1970) on Vicia faba major indicate that grain yields may be doubled when the moisture supply in the top 15 cm of profile is maintained above average levels (ie. greater than 20% of water on a dry soil basis). This was compared to irrigating when visual symptoms of water stress were apparent in the crop (i.e. less than 15% of water on a dry soil basis).

Examination of the irrigation requirements of the horsebean by Gibali et al. (1968) have shown that a frequency of water application of twenty days results in a 25% yield increase over application every 60 days when the amount of water applied is sufficient to raise the level to field capacity plus 10%. This observation is supported by Listowski et al. (1966) who record a 103% increase in horsebean (*Vicia faba minor*) seed yield as the maximum soil water stress was increased from 30 to 70% of available moisture. This increase was also apparent in straw dry matter production for the same moisture treatments.

Jones (1963) using broad beans (*Vicia faba major*) has studied the influence of soil moisture in another fashion. He established a set level of water table at various depths in large pots. The response in seed yield showed that the 25 and 36 cm depth treatments yielded one third more than the 46 and 56 cm depth treatments. This reflects the initial check in growth experienced by the plants before they were able to obtain adequate root development at the deeper water table depths. This emphasizes the need for adequate moisture supply in the initial growth stages if good yields are to be obtained.

Mack et al. (1966) in an examination of pole bean productivity monitored the maximum soil moisture tension at 30 cm depth to determine the required frequency of irrigation to produce optimum yields. When the maximum tension imposed was reduced from 4.5 to 0.9 bars, yields increased by 63%. Kuo and Boersma (1971) report that in the case of three week old soybeans (Glycine Max. (L.) Merr.) as soil moisture tension was increased from 0.35 to 2.50 bars the rate of nitrogen fixation was reduced 41.5% with a corresponding 56% drop in dry matter production. Similarly, Burman and Bohmont (1961) using great northern beans, found that an increase in the maximum soil moisture tension from 0.5 to 1 bar results in a 42% decrease in seed yield.

If soil moisture conditions are inadequate for maximum crop growth performance and the supply of irrigation water is limited, then the growth stage at which the supplemental irrigation is applied may be critical in determining the magnitude of the increase in final dry matter or seed yields (Salter and Goode, 1967). Experimental results of El Nadi (1970) on Vicia faba major show that supplemental irrigation in the pod development to harvest growth stage resulted in a 29% yield increase over a check treatment. This compares with a 10% yield increase when the supplemental irrigation occurred in the emergence to pod development stage. This indicates a greater plant sensitivity of grain yield to soil moisture deficit in the later growth stages. However, maintenance of an adequate moisture supply throughout the entire growing season was clearly the most satisfactory treatment resulting in a 78% yield increase over the drier check treatment.

Salter (1963) examined the yield response of peas to additions of moisture at various growth stages and he considered that irrigation in the preflowering vegetative phase did not increase yields. When the supplemental irrigation was applied only in the flowering stage, seed yield was increased by 30% over the check treatment; similarly water addition only in the pod swelling stage increased yields by 20%. These results emphasize the greater yield response resulting from ensuring an adequate moisture supply in the reproductive growth phases. Salter and Goode (1967) have concluded from the work of Reisch (1952); Stolp (1957, 1960) and Brouwer (1949, 1959) that yields of broad and field beans were also favourably increased by supplemental irrigation during the moisture sensitive flowering stage and that irrigation at the later growth stages was beneficial. However, for Vicia faba major, Jones (1963) considered that the attainment of a high plant growth rate before flowering was essential if good seed yields were to be obtained. Also Maurer et al. (1969) found that there was no significant difference in the total dry matter production of snap beans when a moderate tension treatment (0.5 bar) was imposed in either the seeding to flowering stage or the flowering to harvest stage.

Atmospheric Temperature

It is clear that all crop types do not respond to varying environmental conditions in a similar fashion. Yet near optimal yields can generally be obtained under a range of air temperature regimes given that other factors involved are non-limiting. The identification of the boundaries and extent of this range and the interaction of temperature with other environmental variables for particular crops is as yet only poorly understood. Hodgson (1967) has shown that for Vicia faba equina relative growth rates are positively correlated with light and temperature and are very low (less than 0.06 gm/gm per day) when mean weekly air temperature is less than 9 C. Maximum relative growth rates occurred at the highest mean temperatures experienced in the study (14-16 C). He concluded that horsebeans are less sensitive to seasonal fluctuations in environmental conditions than are sunflowers.

Evans (1957) considered variety to be a critical variable in the response of Vicia faba major to temperature conditions. For fast growing European spring beans maximum growth rates occurred from 23 to 30 C and for the slower growing European winter beans 20 to 26 C was optimal. However at the highest temperatures most varieties were only able to sustain high growth rates for a short period of time and a heavy yield of seed could equally well be obtained at 10 C over seven months as at 23 C over four months. He claimed that these results show that it is not the effect of high temperatures per se that causes bean growth to cease under hot dry field conditions and that Vicia faba major is less adversely effected by high temperatures than peas.

In the case of peas Fletcher et al. (1966) consider that a seasonal average maximum air temperature of 20-21 C represents an optimum level. Nonnecke et al. (1971) claim that an increase in day - night temperature regime from 17/7 to 27/17 C may result in a 70% decrease in seed yield. Stanfield et al. (1966) consider that the optimal temperature range for peas shifts with stage of plant maturity. This is represented by a change from an optimum of 21/16 C at the sixth node stage to 16/10 C at maturity.

Listowski et al. (1966) examined the influence of night temperature regime on the seed yield of Vicia faba minor and concluded that high night temperatures (mean 20 C) resulted in a reduction in yield of 18% compared to a mean night temperature of 11 C. However the influence of night temperature was not considered to be significant compared to soil moisture treatments which recorded a yield increase of 103% when the soil water deficit was lowered from 70 to 30% of available moisture. Evans (1957) supports the conclusion that lower night temperatures are favourable for the productivity of Vicia faba. Peters et al. (1971) report that in the case of soybeans (Glycine Max. L. Merr.) a reduction in the average night temperature from 29.4 to 18.3 C results in a 20% reduction in yield. However, Fattah and Wort (1970) record a 35% increase in the fresh pod weight of bush beans (Phaseolus vulgaris L.) when night temperatures were raised from 21 to 26 C.

C.E.Moore (1974, Personal Communication) suggests that fababeans will tolerate a warm climate up to certain levels (2700 corn heat units) and above this level yield return will be unsatisfactory (the **highest** corn heat unit accumulation in Manitoba is 2500 units). He considers that extremely high temperatures (greater than 32 C) will cause almost complete flower abortion and cessation of pod growth; and satisfactory reproductive development is only likely to occur below 30 C.

Soil Temperature

The productivity of a plant is affected by the development of its root system. This in turn is strongly influenced by the environmental conditions to which it is exposed, of which a major component is soil temperature (Sartain and Nelson, 1970). In the case of innoculated legumes the effect of soil temperature is of added importance as this is a controlling factor in the productivity of the nitrogen fixing root nodule bacteria, which are in general the principal source of nitrogen to the growing crop.

Kuo and Boersma (1971) in a laboratory study using three week old soybeans (*Glycine Max.* (L.) Merr.) indicated that as root temperatures increased from 15.6 to 37.8 C plant dry weight, net photosynthesis and nitrogen fixation rate initially increased slowly and then rapidly to reach optimum values around a temperature of 27 C. This was followed by decreasing values as temperatures increased further. A positive deviation from the optimal temperature of 27 C was shown to result in a reduction in nitrogen fixation rate comparable to that caused by an increase in soil moisture tension from 0.70-1.50 bars.

Mack and Ivarson (1972) in a field experiment using soybeans (*Glycine Max.*) concluded that yield was linearly related to increases in soil temperature and heat accumulation. Experimental results indicated a 43.4% increase in yield when the accumulated soil heat at 20 cm depth was raised from a total of 859 to 1822 day degree units above 5 C. (i.e. The number of degrees C per day by which the mean soil temperature at 20 cm exceeds a base temperature of 5 C, the total being accumulated over the growing season). There was also a matching decrease in yield of 82.4% when the heat accumulation was lowered to 408 units. These values correspond to mean daily soil temperatures of 11.2, 17.7 and 31.2 C and this represents an increase in yield on the warmer soil of 0.54 q/ha per degree C.

The experimental results of Sartain and Nelson (1970) on the soybean concur with previous workers in suggesting that optimum soil temperature values are near 28 C. They also consider that dry matter productivity is satisfactory over the 20-35 C range but that above this value a rapid deterioration in growth performance takes place.

Mack (1973) has shown for field peas (Pisum sativum L.) that considerably higher seed yields were obtained at a mean soil temperature of 10.4 C compared to higher temperatures of 18.5 and 29.2 C. However, maximum vine weights were recorded at the intermediate soil temperature 18.5 C. These values correspond to soil heat accumulations at 20 cm depth of 334, 840 and 1500 units.

Mack and Vallen (1974) in a study on white beans report that a considerable increase in yield occurs when the accumulated level of soil heat at 20 cm depth is raised from 602 to 1004 units (19.7 and 29.7 C temperature treatments), representing a 0.71 q/ha change in yield per degree C from the seasonal mean temperature 19.7 C. This clearly shows that white beans are closely related to soybeans in their soil temperature requirements but field peas require a radically different environment for maximum productivity.

Conclusions

The review of previous research shows that the response of individual seed legume crops to environmental conditions is highly varied. However it is apparent that even moderate deficits in available soil moisture result in reduced crop yields. Vicia faba appears to be relatively sensitive to soil moisture status throughout the growing season particularly in the reproductive growth phase.

It is clear that there will be a significant interaction in the effects of soil moisture, soil temperature and atmospheric temperature; but for non-limiting soil moisture conditions the optimum atmospheric temperature range for Vicia faba minor appears to be between that of peas and soybeans. High day and night temperatures are likely to cause yield reduction and low temperatures will probably reduce the crop growth rate. The effect of soil temperature variation on seed yield is not presently known for this crop.

III MATERIALS AND METHODS

Field Investigations

The locations of the experimental plots were specifically chosen in order to embrace the widest possible range of climatic conditions in Southern Manitoba. This was determined with reference to maps prepared by Shaykewich(1974). In particular the soil water deficit on September 30th map and the degree days above 5 C May 1st - September 30th map were utilized to choose plots with as large a variation in plant available soil moisture and air temperature conditions as possible. The sites chosen were Altona, Seven Sisters and Pilot mound; site descriptions are displayed in Tables 1 and 2.

Seeding dates were 4 - 5 weeks later than is recommended; the delay being caused by May rains and the need to share equipment time. The plots were strips (40 m x 5 m) located adjacent to fababean fertilizer trials which helped to reduce any bias in the data analysis from climatic "edge effects". Seeding rates (200 kg/ha) were greater than recommended and commercial innoculum (Nitragin (faba bean) Q culture Lot No. X27.)[1] was applied at a rate of 418 gm per 100 kg of seed. Convential seeding equipment was used. Adequate weed control was obtained by the use of Treflan

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[1] Supplier - Nitragin Co., Milwaukee, Wisconsin 53209, USA.

at the recommended rate as a pre-emergence herbicide for control of wild oats. Broadleaved weeds were removed by weekly handweeding of all plots.

Triple super phosphate was applied at a rate of 15 kg of P per hectare to ensure adequate availability of phosphorus to the crop. Adequate to good emergence was achieved at all sites with very few gaps in the plant stand. The plant densities (means of 15 random metre quadrats) were: Altona 56 plants/sq.m, Pilot Mound 66 plants/sq.m and Seven Sisters 44 plants/sq.m.

Environmental Parameters Recorded. Rainfall and daily maximum and minimum air temperatures were recorded from seeding to harvest either on site or in weather stations within a two mile radius of the plot. Weekly potential evapotranspiration values (cm) were calculated from this data using the shortened Baier and Robertson (1965) formula:

$$PE = (-87.03 + 0.928 Tmax + 0.933 Range + 0.486 Qo) \times 0.00864$$

where Tmax = Daily maximum air temperature

Range = Daily maximum - daily minimum air temperature

Qo = Solar energy falling on a horizontal surface at the top of the atmosphere in cal/sq.cm during one day.