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INTERACTIONS BETWEEN FALLOW LENGTH, PHOSPHORUS AND ZINC SUPPLY ON THE PERFORMANCE OF SPRING AND AUTUMN SOWN SUNFLOWER.

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SUMMARY

Extended periods of long fallow are common in central Queensland. Such fallows aggravate phosphorus (P) deficiency but the reasons are not clear. We studied the interacting effects of fallow length, sowing time, P and zinc (Zn) fertilization on the performance of 6 sunflower gentoypes on an infertile vertisol in semi-arid central Queensland, Australia.

Plant weights were recorded after the accumulation of 600 heat units, P deficiency symptoms noted and roots analysed for vesicular-arbuscular mycorrhizae (VAM) infection. Flowering was recorded in remaining guard plants.

Poor growth in long fallowed plots (long fallow disorder, LFD) was prevented by adding P, breaking the fallow or utilizing a short fallow. Soil P values (13 mg kg^{-1}) were not affected by fallow length and were not related to differences in growth among fallow lengths. Roots were heavily infected with VAM (>40%), more so in medium and short fallow plots and the proportion of VAM infected roots varied significantly among genotypes in the autumn planting. Three times as much infected root was present in the short fallow than in the other fallows. LFD was attributed to declining VAM infectivity, as fallow lengthened, and hence reduced P uptake. Overall Hysun 33 grew the fastest, while Hysun 22 was the slowest, particularly in P treated plots. The appearance of foliar P deficiency symptoms varied among genotypes but was absent from plants that yielded more than 40% of their potential. Flowering was delayed by up to 13 days by P deficiency, with the delay varying among genotypes and with season. Because this delay allows plants to recover from P deficiency, a case for selecting plants with a well developed delay mechanism is presented. Although soil DTPA Zn was low (0.8 mg kg^{-1}) there was little evidence that Zn was a limiting nutrient under the conditions of this experiment.

EFECTOS INTERACTIVOS ENTRE OPORTUNIDAD DE BARBECHO Y LA APLICACION DE FOSFORO Y ZINC SOBRE EL COMPORTAMIENTO DE GIRASOL SEMBRADO EN PRIMAVERA Y OTOÑO

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RESUMEN

Las labores culturales de barbecho requieren de especiales condiciones ambientales. En las regiones centrales de Queensland la oportunidad de realizar dichas práticas entre ciclos de cultivos generalmente varía entre doce y diociocho meses. Estas prácticas hacen más restrictivas las deficiencias de fosforo (P), cuyas razones aún son desconocidas. En este experimento fueron estudiados los efectos interactivos entre oportunidad de barbecho, época de siembra y la aplicacion de P y zinc (Zn) sobre el comportamiento de 6 genotipos de girasol, sembrados sobre un vertisol de baja fertilidad en una región semi-arida en el centro de Queensland Australia.

Los pesos de las plantas fueron determinados después de la acumulacion de 600 unidades de calor, los sintomas de deficiencia de P fueron observados y las raices fueron analizadas mediante la infección vesicular-arbuscular por mycorrhizae (VAM). La floración fue determinada en plantas pertenecientes a las áreas de protección.

El pobre crecimiento en los lotes con largos periodos de barbechos fue superado mediante la adición de P ó interrumpiendo el largo periodo de barbecho. La cantidad de P en el suelo (13 mg kg^{-1}) no fue afectada por la baja frecuencia de barbecho, tampoco tuvo efectos interactivos con las diferencias en crecimiento entre los tratamientos de barbecho aplicados. Las raices fueron grandemente infectadas con VAM (> 40%), principalmente en las parcelas con media y alta frecuencia de barbecho y la proporcion de VAM en las raices infectadas varió significativamente entre genotipos en la siembra de ótoño. La cantidad de raices infectadas fue tres veces mayor en los lotes con alta frecuencia de barbecho en comparacion con las otras frecuencias probadas. Los efectos negativos causados por los largos periodos entre dos ciclos consecutivos de barbecho fueron atribuidos a la baja infectividad de VAM cuando el periodo de barbecho fue extendido y por consguiente la absorsión de P fue reducida. Los genotipos Hysun 33 y Hysun 22 mostraron los crecimientos más rápido y más lento respectivamente en comparación con los otros genotipos ensayados, particularmente en las parcelas fertilizadas con P. Los sintomas aparentes de la deficiencia foliar de P, varió entre genotipos pero estuvo ausente en plantas que rindieron más de 40% de su potencial. La floración fue retrasada hasta 13 dias por la deficiencia de P, dicho retraso fue diferente entre genotipos y entre estaciones. Debido a que este retraso permite a las plantas recuperarse de la deficienciá de P, una alternativa para selecionar plantas con un mecanismo de retraso es presentado. Aunque la cantidad de Zn fue baja (0.8 mg kg^{-1}) no hubo evidencias de que este micro-nutriente fuera limitativo bajo las condiciones de este experimento.

INTRODUCTION

Because of the unreliability of rainfall in central Queensland, the duration of the bare fallow period between crops is variable and unpredictable. Periods exceeding two years are not uncommon. While fallows are usually considered beneficial, Leslie and Whitehouse (1968) noted that phosphorus (P) deficiency in wheat in the region was actually worse following a long fallow, than after a short fallow. Hunter and Kochman (1985) reported very poor growth in field sunflowers (11% of P fertilized plots) following a very long fallow and were able to aggravate this P deficiency even further (1-3% of maximum growth), together with the expression of characteristic deficiency sumptoms, by heat sterilizing the soil prior to its use in pot culture.

Thompson (1987) has shown in pot culture that this poor growth, locally referred to as Long Fallow Disorder, can be attributed to the declining root infection (or absence in sterilized soil) of root fungi (vesicular-arbuscular mycorrhizae (VAM)) that form a very important symbiotic relationship with most crop plants that grow in infertile soil. In exchange for carbohydrates from the plant, these fungi can supply the plant, via extensive mycelial networks in the soil, with immobile nutrients such as P (Mosse, 1973) and zinc (Zn) (Gilmore, 1971), much of which the plant may otherwise be unable to absorb. The probable role of VAM in the P nutrition of sunflowers in central Queensland has been highlighted previously (Hunter and McCosker, 1982; Hunter and Kochman, 1985; Hibberd and Hunter, 1985) and its almost obligate dependance on VAM for P in the low P soils of the region demonstrated (Thompson, 1987).

The failure of soil P tests to consistently explain subsequent crop performance may be attributed to the use of an inappropriate extractant (Holford, 1985). However, this assumes that important factors of the environment that determine P accession can be accounted for satisfactorily. Unfortunately, few soil scientists are aware of the role that soil organisms such as VAM have in P uptake, or acknowledge the marked effect that they can have on the interpretation of soil P concentrations in fertilizer management.

We show how fallow length and season can affect the responses of six sunflower hybrids to applications of P and Zn and discuss the likely involvement of VAM in the expression of and recovery from P deficiency.

MATERIALS AND METHODS

The experiment was located on a flat pellic vertisol or black earth (P. Shields pers. comm.) 5 km south of Biloela, lat. 24.38, long. 150.55. Duplicate portions of the area were bare fallowed following sunflowers in (i) June 1982, (ii) July 1983 and (iii) July 1985. Each portion was divided in two, and one half sown in spring on 17/9/85 and the other in autumn on 14/3/86. Four fertilizer treatments (0; 80 kg ha^{-1} P; 5 kg ha^{-1} Zn; 80 kg ha^{-1} P + 5 kg ha^{-1} Zn) were banded approximately 10 cm deep in two 6 m long rows, 70 cm apart. Nitrogen was added as calcium nitrate in all bands at a rate of 50 kg ha^{-1} N and gypsum (calcium sulphate) added so that total S addition from the various sources was constant at 9 kg ha^{-1}. Six sunflower genotypes (Table 1) were hand planted into dry soil at 15cm intervals 5 cm deep directly above the fertilizer band (2 m of row per genotype) and then watered up with overhead irrigation. In summary, the principal experiment was a five factor (2 sowing times, 3 fallow lengths, 2 P rates, 2 Zn rates and 6 genotypes), triple split, twice replicated factorial. In addition, the unfertilized (for P and Zn) plots in the July 1983 and 1985 fallows of the spring planting were resown in the autumn planting along the original rows with minimal soil disturbance and the omission of any additional fertilizer. In effect these plots were medium and short fallow treatments broken by the short period of growth in spring prior to replanting in autumn.

Fresh weights of ten whole plants were measured following the accumulation of 600 heat units [base of 6°C, Σ ($\frac{\text{daily max.} + \text{daily min.}}{2} - 12$)], on 30/10/85 for the spring plant (43 days) and on 17/4/86 for the autumn plant (34 days). Symptoms of P deficiency (Hunter and Kochman, 1985) were recorded in five plants per plot.

At harvest, 20 cm deep soil cores containing ≈ 2 kg moist soil were collected from the base of five plants in plots in which P had been omitted. Roots were recovered by wet sieving, cleared of cytoplasm in a 10% KOH solution and immersed in a glycerol 0.05% Trypan Blue solution to stain structures of the VAM fungi present in the root (Phillips and Hayman, 1970). The gridline intersect method (Giovannetti and Mosse, 1980) was used to estimate proportion of roots infected with VAM. The relative quantities of VAM infected roots were estimated by multiplying percentage root infection by shoot weight, assuming that shoot: root relationships were not greatly affected by treatments. Times to flowering were recorded in the guard plots of the longer fallowed plants only in the spring planting and in all fallows in the autumn planting. Soil samples (0-60 cm) from the site were analysed for P and Zn (Table 2).

Table 1. Effect of planting date and P fertilization on fresh shoot weights of 6 sunflower genotypes.

Plant Date	P ($kg\ ha^{-1}$)	Shoot fresh wt of sunflower genotypes ($g\ plant^{-1}$)					
		Hysun 33	Hysun 32	Pioneer 02005	Suncross 25	Hysun 22	Dynamite
17.9.85[1]	0	44	46	36	34	37	38
	80	150	146	137	139	115	150
14.3.86[2]	0	37	29	43	34	34	34
	80	82	68	77	80	70	74

[1, 2] harvested at day 43 and 34 respectively. Plant date x P x genotype sig. at $P<0.05$ with LSD ($P=0.05$) of 8. Data meaned over 3 fallow lengths and two zinc rates.

RESULTS

Growth. Part of the apparent interaction of seasonal effects on growth responses to P (Table 3) is attributed to the much lower rainfall on the autumn planting (8 mm) than on the spring planting (133 mm). While both unfertilized June 1982 (long) and July 1983 (medium) fallows severely depressed growth in both plantings compared with growth in July 1985 (short) fallow, this effect was removed by the addition of phosphorus. Furthermore, the depressive effect of medium fallow in the second planting was also removed by the prior growth of sunflowers, even if very slowly, for 43 days in the first planting (Table 3).

Table 2. Effects of fallow length on concentrations of phosphorus (bicarbonate extractant, Colwell, 1963) and zinc (DTPA extractant, Lindsay and Norvell, 1978) from trial site (0-60 cm depth).

Start of fallow	Nutrient extracted	Nutrient concentration ($mg\ kg^{-1}$) Soil depth (cm)		
		0-10	10-20	20-60
June 1982	P	15	6	4
July 1983		11	6	5
July 1985		13	6	4
Mean		13	6	4
June 1982	Zn	0.8	0.7	0.5
July 1983		0.8	0.5	0.4
July 1985		1.0	0.7	0.4
Mean		0.8	0.6	0.4

The highly significant ($P<0.01$) interaction of gentoype growth rate with planting date and phosphorus supply is shown in Table 1. A slight positive growth response to Zn occurred (6%) but this was overshadowed by the large P response (189%). Significant growth interactions between zinc and other factors appeared inconsistent and are not reported.

VAM infection. Roots of plants in minus P plots were heavily infected with VAM, with plants in the autumn planting being more heavily infected (53%) than in the spring planting (40%, $P=0.02$). Roots of plants growing in medium and short ion for this trait in genotypes being bred for low P soils could be a worthwhile goal. It is clear that the effects of planting time, P supply and fallow length, as well as variation in flowering time among genotypes, must be accounted for by hybrid seed producers, plant modellers and breeders on low P soils, if predictions of plant growth are to be realized.

Although Zn deficiency has been implicated elsewhere in the expression of Long Fallow Disorder (Thompson, 1987), zinc did not emerge clearly as a limiting nutrient in this experiment, despite its marginal status. Likewise zinc deficiency did not develop in pot culture in a similar soil of similar zinc status despite soil sterilization to remove VAM (Thompson, 1987). However, soils in the region are known to have as little as 0.2 mg kg^{-1} Zn and the likely interaction of VAM infectivity in Zn accession, similar to that of P must not be overlooked at other sites. It is interesting to note that zinc deficiency in field grown sunflowers has yet to be reported (Blamey et al., 1987) perhaps because of the effectiveness of the associated VAM organisms in their accession of soil zinc.

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