INTERACTIONS BETWEEN MOISTURE SUPPLY, N AND P, IN THE PERFORMANCE OF AN OPEN-POLLINATED AND A HYBRID SUNFLOWER VARIETY IN A SEMI-ARID ENVIRONMENT.

M.N. HUNTER and A.N. McCOSKER
Department of Primary Industries, P.O. Box 201, Biloela, Qld. 4715. Australia.

ABSTRACT

The interacting effects of moisture supply, N and P on the production of an open-pollinated (OP) sunflower cultivar (Sunfola 68-2) and a hybrid (Hysun 30) were studied in a black cracking clay of Central Queensland. Mean seed yields (1764 kg ha^{-1}) in the wet environment (WE 170 mm "rain") exceeded yields (1150 kg ha^{-1}) in the dry environment (DE 93 mm rain). Maximum seed yield responses to nitrogen of 24% at 120 kg ha^{-1} and 18% at 40 kg ha^{-1} occurred in the WE and DE respectively. P increased seed yield by 14% but only in the DE. Irrespective of moisture supply the hybrid accumulated dry matter more rapidly than, and outyielded, the OP in seed and oil yield. In the DE the seed yield of the hybrid was more responsive to nitrogen than the OP. At similar oil yields Sunfola 68-2 removed 22% more N and P in seed than did Hysun 30.

INTRODUCTION

Much of Australia's sunflower seed is produced in Central Queensland on heavy black cracking clay soil of basaltic origin. In many areas this soil is considered to be deficient in nitrogen (N) and phosphorus (P). Grain yield responses in wheat to fertilizers in Central Queensland have been confounded by great seasonal variation in moisture supply. (W. Strong, personal communication). With the expansion of the sunflower industry a programme directed at providing guide lines for fertilizer use in sunflowers was initiated by the Queensland Department of Primary Industries. This paper outlines the magnitude of crop response in an open-pollinated and a hybrid sunflower to the application of nitrogen and phosphorus to an infertile soil, under two moisture supply conditions.

MATERIALS AND METHODS

The experiment was conducted on an alluvial black cracking clay low in P (12 ppm bicarbonate extracted, 0 — 30 cm) and N (19 kg ha^{-1} NO_3–N, 0 — 60 cm) in two adjacent blocks. One block was irrigated on day 35 (26.5 mm), day 39 (23.9 mm) and day 61 (27.3 mm) to simulate "rainfall events, additional to natural rainfall on day 6 (19.8 mm), day 19 (19.8 mm) day 63 (5 mm) and day 69 (11 mm). Another 29.7 mm of rain also fell to give a total of 93 mm, but this amount occurred in falls that were all less than 4 mm and considered ineffective. Available soil moisture to 1 metre depth at planting was approximately 160 mm. An open-pollinated cultivar, Sunfola 68-2 and a hybrid, Hysun 30 were planted in metre rows on 27 February 1979 in the rainfed block (DE) and one day later in the irrigated block (WE). Nitrogen (N), as urea, and phosphorus (P), as double superphosphate, were applied 5 cm below and 5 cm to the side of seed in separate bands either side of the seed. In the DE, N was applied at 0, 10, 20, 40, 60 and 80 kg N ha^{-1} and in the WE at 0, 40, 80, 120, and 160 kg N ha^{-1}. In both blocks P was applied at 0 and 40 kg P ha^{-1} in factorial combination with N rates. All treatments were replicated twice. Ten days after sowing plant population was reduced to 50,000 plants ha^{-1}. Dry matter was collected from 2 m of row on days 17/18, 37/38, 62/63 and 82/83 from the WE and the DE respectively. After all leaves had dried, heads were hand harvested from 10 m of row, bounded on each side and each end with guard rows, on days 107/108 for Sunfola 68-2 and on days 120/121 for Hysun 30. Seed weights (200 seed) were measured and seed analysed for oil, nitrogen and phosphorus concentration. Analyses of variances of data from the DE and WE were calculated independently. Data of common treatments from both environments were also analysed on a combined basis to assess the magnitude of the moisture interaction. Average monthly maximum/minimum temperatures were for March 29.2/15.8°C, April 28.7/11.4°C, May 24.1/6.9°C and June 23.0/6.0°C. Flowering (50% anthesis) occurred in Sunfola 68-2 on day 57 ± 1 and in Hysun on day 67 ± 1.

RESULTS

Nitrogen fertilization increased seed yield (Figure 1) and also increased oil yield and the amount of nitrogen in the seed (data not shown).

Figure 1. Effect of nitrogen fertilization on seed yield (9% m.c.) of two sunflower cultivars grown under two moisture supply conditions. Curves are hand fitted.

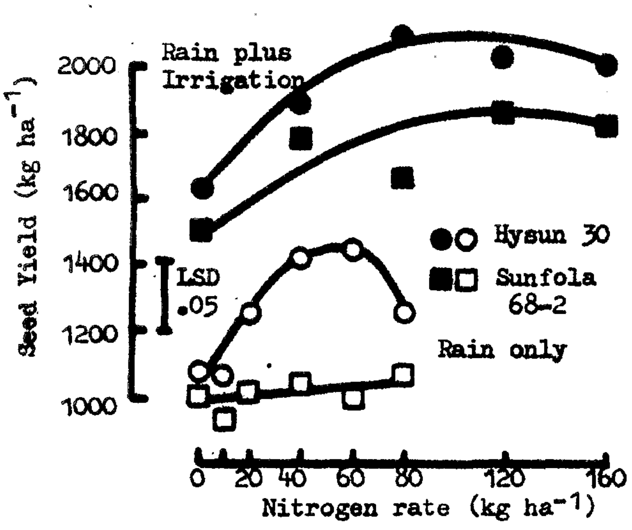
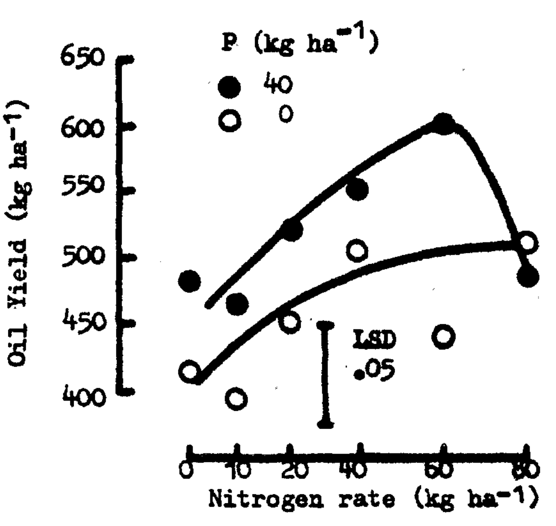


Figure 2. Effect of phosphorus fertilization on response of oil yield to nitrogen fertilization under rainfed conditions. Curves are hand fitted.



Averaged across all other treatments P only increased the production of dry matter (Table 1). Dry matter, seed yield and yield components were increased by the greater moisture supply of the WE (Table 2) whereas oil concentration was unaffected. Averaged across all environments, dry matter, seed yield, oil concentration and oil yield and number of seed produced were greater in Hysun 30 than in Sunfola 68-2 (Table 3). Seed weight, N and P concentrations in seed were greater in Sunfola 68-2 than in Hysun 30.

Table 1. Effect of moisture supply on response of sunflower to phosphorus fertilization, averaged over nitrogen rates and two sunflower cultivars.

Moisture supply			Phosphorus rate ($kg\ ha^{-1}$) 0	40	Response[1] %	LSD (P = 0.05)
Rainfall (DE)	Dry matter ($kg\ ha^{-1}$)	Day 18	18	28	57	4**
		38	853	1181	38	114**
		63	3347	3515	5	ns
		83	4111	4446	8	317*
	Seed yield ($kg\ ha^{-1}$)		1062	1210	14	72.1**
	Seed weight ($g\ 1000\ seeds^{-1}$)		33	33	0	ns
	Seed no. (ha^{-1}) x 10^7		3.15	3.47	10	0.24
	Oil concentration (%)		47.0	47.0	0	ns
	Oil yield ($kg\ ha^{-1}$)		454	518	14	44**
	Seed nitrogen concentrations (%)		3.05	3.12	2	ns
	Nitrogen yield ($kg\ ha^{-1}$)		29.39	34.17	16	2.19**
	Seed phosphorus concentration (%)		0.39	0.43	10	ns
	Phosphorus yield ($kg\ ha^{-1}$)		3.77	4.65	23	0.56**
Rainfall plus Irrigation (WE)	Dry matter ($kg\ ha^{-1}$)	Day 17	13	18	43	3**
		37	641	1001	56	74**
		62	3887	4446	14	341**
		82	5505	5592	2	ns
	Seed phosphorus concentration (%)		0.44	0.47	7	0.03

Variances attributed to variables not shown were not significantly different from the error variance ($P < 0.05$). *$P < 0.05$, **$P < 0.01$. [1]100(value at P_{40} ÷ Value at P_0) − 100

Table 2. Effect of water supply on the performance of sunflower. Results averaged over N rates, P rates and two sunflower cultivars.

Crop Variable		Moisture supply: 93 mm as rain (DE)	93 mm + 78 mm[1] (WE)	Response[2] %	LSD (P = 0.05)
Dry matter ($kg\ ha^{-1}$)	62/63 days	3485	4180	20	32
	82/83 days	4415	5505	25	383
Seed yield ($kg\ ha^{-1}$, 9% mc)		1150	1764	53	221
Seed weight ($g\ 1000\ seeds^{-}$)		33	39	18	3
Seed no. (ha^{-1})		3.36	4.40	31	0.74
Oil concentration (%)		47.04	46.15	−2	ns
Oil yield ($kg\ ha^{-1}$)		493	741	50	70
Nitrogen yield ($kg\ ha^{-1}$)		32.0	51.2	60	5.2[3]
Phosphorus yield ($kg\ ha^{-1}$)		4.2	7.6	79	2.8

[1]26.5 mm day 35, 23.9 mm day 39, 27.3 mm day 61. ns = not significant.
[2]100 (column WE ÷ column DE) − 100; [3]unequal variances in combined analysis.

Table 3. Comparison of the performances to two sunflower cultivars, averaged across different nitrogen, phosphorus and moisture supply environments.

		Sunflower Cultivar: Sunfola 68-2	Hysun 30	Difference[1] %	LSD (P = 0.05)
Dry matter ($kg\ ha^{-1}$)	Day 17/18	1.6	2.2	38	0.3**
	37/38	84.3	102.6	22	8.7**
	62/63	366.9	402.3	10	29.6*
	82/83	451.8	540.1	20	33.3**
Seed yield ($kg\ ha^{-1}$)		1352.6	1561.6	15	85.2**
Seed weight ($g\ 1000\ seeds^{-1}$)		40	29	38	2**
Seed no. (ha^{-1}) x 10^7		2.86	4.90	71	0.23**
Oil concentration (%)		46.1	47.1	2	0.35**
Oil yield ($kg\ ha^{-1}$)		566	667	18	35**
Seed nitrogen concentration (%)		3.35	2.91	15	0.12**
Nitrogen yield ($kg\ ha^{-1}$)		41.5	41.6	0	ns
Seed phosphorus concentration (%)		0.48	0.41	17	0.38**
Phosphorus yield ($kg\ ha^{-1}$)		6.0	5.9	2	ns

[1]100 (Large value ÷ small value) − 100; **$P < 0.05$, **$P < 0.01$.

In the DE maximum oil yield occurred at the highest rate of nitrogen (80 kg ha^{-1}) in the absence of phosphorus, whereas in the presence of phosphorus this rate of nitrogen reduced yield from the maximum (Figure 2). Although N increased seed number and weight by 11% and 7% respectively in the DE and by 15% and 18% in the WE only responses in the WE were significant. Highly significant responses to P fertilization in yield and yield components were restricted to the DE (Table 1). Phosphorus increased seed and oil yield by 14% and also increased the quantities of N and P removed with the seed. The number of seed harvested was increased by 10% in P treatments whereas seed weight was unaffected. As a result of greater moisture supply the number of seed harvested increased, but more so in Hysun 30 than in Sunfola 68-2 (Table 4). Seed weights were also larger in the WE, but responses to irrigation in seed weights were greater in Sunfola 68-2 than in Hysun 30 (Table 4). Both seed yield and oil yield increased in Hysun 30 following N fertilization, irrespective of moisture supply, whereas positive responses in seed and oil yield to N only occurred in Sunfola 68-2 in the wetter environment (Figure 1).

Table 4. Effect of moisture supply on seed number and seed weight in two sunflower cultivars.

Moisture supply	Sunflower Cultivar	Seed number (ha^{-1}) x 10^7	Seed weight (g 1000 $seeds^{-1}$)
Rainfall (DE)	Sunfola 68-2	2.51	39
	Hysun 30	4.21	27
Rainfall plus Irrigation (WE)	Sunfola 68-2	3.21	47
	Hysun 30	5.58	31
	LSD (P = 0.05)	0.33**	3*

*$P < 0.05$; **$P < 0.01$.

DISCUSSION

Greater moisture supply increased yields (Figure 1, Table 2). Efficiency in utilizing the additional simulated rainfall of 78 mm was 78.7 kg seed ha^{-1} cm^{-1} (or 31.8 kg oil ha^{-1} cm^{-1} of water applied) which exceeded values of 62 (Unger *et al.,* 1976) 50 and 66 kg seed ha^{-1} cm^{-1} of water used (Robinson, 1978). Efficiencies as high as 140 kg seed ha^{-1} have been reported (Milic, 1967).

The need to examine nutritional responses in seed yield under variable moisture supply conditions is shown in Figure 1, in which the responsiveness of Sunfola 68-2 to applied N was clearly dependent on moisture supply. Data in Table 1 indicates that moisture supply also had an important influence on responses of seed production to applied P.

The need for applied P was greater under the drier conditions despite the 81% greater P yield in grain produced under the wetter conditions. Such results do not agree with current recommendations (Danke *et al.,* 1981; Dowdle, 1977) which indicates the need to use greater amounts of P to meet the requirements of increasing yield goals. In this soil extractable P concentration declines markedly with depth. Thus the surface soil would be a most important source of P. Since root exploration and exploitation of the surface soil for P would be directly related to moisture content a greater uptake of native P would be expected under wetter conditions. Such uptake would diminish the need for fertilizer P.

Spencer and Chan (1981) reported large dry matter responses to applied P in sunflowers (204%) at 42 days but much smaller responses (55%) in seed yield in the same crop. Similarly in this experiment seed yield responses to P were much smaller, and even absent in the WE, than the dry matter responses to phosphorus (Table 1). This decline in response may be expected where the large dry matter response in P supplied plants subsequently disappears through the imposition of another limiting factor such as water. However, this was not the case in this experiment since no seed yield response to P occurred in the WE. Recently, sunflower roots extracted from a black earth with $\leqslant$8 ppm bicarbonate extractable P concentration were found to be very heavily infected with mycorrhizal hyphae (D. Hibberd, J. Thompson, personal communication). This infection was found on plants that yielded 2955 kg ha^{-1} seed without the addition of P. Mycorrhizae are known to have a marked positive effect on P nutrition of plants grown in infertile soils (Mosse, 1973; Tinker, 1975) and their development within and around a developing sunflower root system and subsequent contribution to plant P uptake may explain why large responses in growth to applied P early in the growth cycle do not carry through into seed yield responses.

By contrast, applied N did not increase dry matter production but increased seed yield and oil yield, suggesting that native N supply became limiting after the vegetative phase had been completed. Nitrogen accumulation in the seed was much greater (59%) when additional water was supplied despite the absence of applied nitrogen. Obviously water supply in this semi-arid environment has a huge influence on the utilization of native N, and therefore the need for applied nitrogen to meet a particular yield goal.

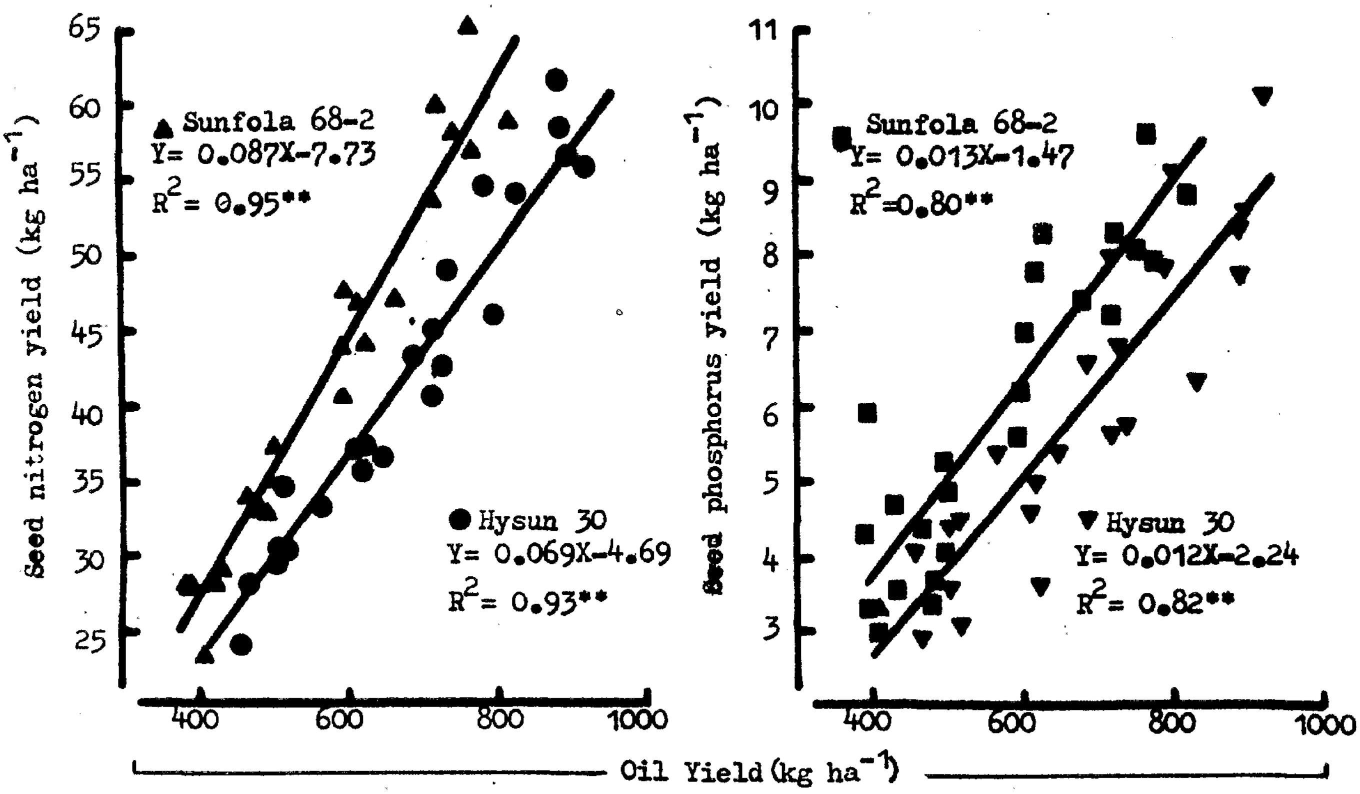
The examination of seed weight and seed number gives some insight into how stress levels of the various factors have influenced seed production. Thus in this experiment the positive effect of P on yield occurred almost entirely through its effect of increasing seed number; an effect that probably occurred early in the crop cycle (Table 1). By contrast, both seed weight and number responded similarly to N, supporting other similar results (Massey, 1971). The greater moisture supply increased seed number proportionally far more than seed weight, particularly in the case of Hysun 30 (Table 4). Part of this difference between cultivars may be explained by differences in moisture supply at flowering.

Oil yields are the ultimative objective in sunflower production and curves in Figure 2 show that in the DE applied P increased yields together with nitrogen rates up to 40 kg ha^{-1}. Oil yield in the WE maximized at a nitrogen rate between 40 and 120 kg N ha^{-1}, irrespective of the use of phosphorus. Assuming 19 kg extractable NO_3-N was available at planting, estimated requirements, based on a yield goal of 1300 kg ha^{-1} in the DE and 1730 kg ha^{-1} in the WE would have been 46 and 67 kg fertilizer N ha^{-1} respectively (Wagner *et al.,* 1975). Such predictions based on experience in North Dakota of USA may be a useful guide to nitrogen usage in Central Queensland. However, aspects such as cropping sequences that include grain legumes and N accumulation below 60 cm and their effects on N requirements need also to be considered.

The two sunflower cultivars were selected as representative of portion of the available germplasm base. Under conditions of this experiment the hybrid grew more rapidly, an advantage in competing with weeds. While both cultivars yielded similarly under N deficient conditions the hybrid responded more to N fertilization. The hybrid produced smaller seed than the OP, but a much greater number of seed resulting in consistently greater yields of seed and oil in the hybrid. Prolificacy of seed may impart greater homeostatic capacity to sunflower under the wide range of environments experienced in Central Queensland. Part of the greater yield of the hybrid may also lie in its longer growing period, and thus its greater opportunity to exploit the environment.

Nutrient removal in seed of those nutrients in marginal supply must be minimised, provided they do not form a basis for economic return. The concentration of both nitrogen and phosphorus in seed was less in Hysun 30 than in Sunfola 68-2, while the converse was true for oil concentration. Regressions of elemental yield against oil yield (Figure 3) revealed that within the range of yields recorded in this experiment 22% more nitrogen and phosphorus were removed in the seed of Sunfola 68-2 than in Hysun 30 at the same oil yield (715 kg ha^{-1}).

Figure 3. Relationship between oil, nitrogen and phosphorus yields in two sunflower cultivars.



Such differences between cultivars in their capacity to deplete an environment of scarce resources should be recognized as an important criterion on which to discard cultivars. In any economic analysis the replacement cost as fertilizer of a particular element removed in the seed should be considered.

ACKNOWLEDGEMENTS

This work was supported by the funds provided by Australian Oilseed Research Committee. Thanks are extended to Mr. B. Van Itallie for use of his land and to Mr. A.A. Webb and Mr. W.H. Hazard for their supervision and encouragement in the course of this work. The support given by Dr. J. Standley and the statistical analyses provided by Mr. A. Lisle are greatly appreciated.

LITERATURE CITED

DANKE, W.C., AUBRISKI, J.C. and VASEY, E.H. 1981. Fertilizing sunflowers. *Circular* SF-713.

DOWDLE, W. 1977. Sunflower... fertility key issue. *Sunflower* 1, 3 and 22.

MASSEY, J.H. 1971. Effects of nitrogen rates and plant spacing on sunflower seed yields and other characteristics. *Agronomy Journal* 63, 137 — 138.

MILIC, M. 1967. Irrigation rate and fertilizer application to sunflower in Metohija. Savp. *Poljopr* 15, 973 — 980 (cited by Robinson, 1978).

MOSSE, B. 1973. Advances in the study of vesicular arbuscular mycorrhizas. *Annual Review of Phytopathology* 11, 171 — 195.

ROBINSON, R.G. 1978. Adaptation and physiological characteristics of the sunflower plant. In "Sunflower Science and Technology" Ed. J.F. Carter No. 19 Agronomy Series American Society of Agronomy.

SPENCER, K. and CHAN, C.W. 1981. Critical phosphorus levels in sunflower plants. *Australian Journal of Experimental Agriculture and Animal Husbandry* 21, 91 — 97.

TINKER, P.B. 1975. Effects of vesicular arbuscular mycorrhizae on higher plants. *Symposium Society of Experimental Biology* 29, 325 — 349.

UNGER, P.W., ALLEN, R.R., JONES, O.R., MATHERS, A.C. and STEWART, P.A. 1976. Sunflower research in the southern high plains — a progress report. *Proceedings Sunflower Forum* (Fargo, N.D.) 1, 24 — 29.

WAGNER, D.F., DAHNKE, W.C., ZIMMER, D.E., AUBRISKI, J.S. and VASEY, E.H. 1975. Fertilizing sunflowers. *North Dakota Agricultural Extension Circular* SF 3, 1 — 4.