7th International Safflower Conference
WAGGA WAGGA AUSTRALIA

No-till, N fertilization and rotation on safflower performance

Yau S.K.
FAFS, American Univ. of Beirut, Bliss St., P. O. Box 11-236, Beirut, Lebanon, sy00@aub.edu.lb

Abstract
Conservation tillage prevents soil erosion and has other beneficial effects leading to agriculture sustainability. The main objective of this study was to evaluate conservation tillage on safflower performance since no study has been reported. Effects of N application and rotation were also studied. A 2-years rainfed field experiment was conducted in the semi-arid northern Bekaa Valley of Lebanon, which has a cool Mediterranean climate. In 2005-06 and 2006-07, tillage and N rate, and tillage and rotation were the 2 factors studied, respectively. Tillage consisted of 3 treatments: conventional (CT), minimum (MT), and no tillage (NT). The 2 treatments of N rate were 0 and 40 kg N/ha. Rotation included growing safflower after a previous crop of safflower, chickpea, or barley. Tillage x year was significant for seed yield; yield under MT was lower than that of NT and CT in 2005-06 but not in 2006-07. Mean seed yield under NT was similar to that under CT. Nitrogen fertilization did not increase seed yield as harvest index was reduced, though N application led to earlier flowering, taller plants, and higher dry matter yield at flowering. The one year rotation study did not show a significant effect of previous crops on seed yield although there were more weeds, less crop growth, and shorter plant height during early growth stages after safflower than after barley or chickpea. In conclusion, this study showed that safflower is suitable to be grown under NT and there is no need to apply N to safflower when it is grown after fertilized cereal crops.

Key words: Seed yield – conventional tillage – minimum tillage – rotation – Mediterranean

Introduction

Safflower (*Carthamus tinctorius* L.) is originated from the eastern Mediterranean, and is adapted to semi-arid areas receiving winter and spring rainfall with a dry atmosphere during flowering and maturation. Although safflower has been grown in West Asia and North Africa for a long time, interest to explore growing safflower for edible oil started not long ago in the region (Hajichristodoulou, 1985; Pala and Beg, 1997). Yau et al. (1999) presented reasons to support safflower cultivation in the region, Lebanon in specific, and a recent study showed that growing safflower brings in higher income than barley, lentil and chickpea (Yau, 2004).

Conventional tillage (CT) that involves ploughing followed by cultivation has been practiced for centuries. However, CT leads to soil erosion and loss of organic matter leading to un-sustainability of agriculture. As a remedy, conservation tillage that includes minimum tillage (MT) and no tillage (NT) has been widely accepted by farmers in many developed countries. Many studies showed that NT has economic, ecological, environmental, and social benefits. These include erosion control, water conservation, nutrient cycling, time and fossil fuel saving, less wear and tear on machinery, and soil carbon sequestration (Lal, 2007). However, little research has been conducted on conservation tillage in West Asia and North Africa, not to mention tillage research on safflower.

Nitrogen is a costly input and excessive application will lead to pollution of ground water with nitrate. Unfortunately, there were contrasting reports on the optimal rate of N fertilization in safflower. Earlier, it was accepted that safflower have a similar N requirement as wheat. However, there has been a major change in opinion on N fertilization on safflower recently. Safflower is generally known to have deeper roots than wheat or other small grains, thus it may use nutrients and moisture that are unavailable to the cereals. Safflower has been shown to effectively use carryover N from prior cropping to depths of 2 m (Tanaka and Merrill, 1998), and no significant yield response to N application was detected in rainfed trials (Yau and Ryan, 2003) and in irrigated trials (Yau and Nimeh, 2005). However, N management guides established under conventional tillage may not be applicable under the no-till system since the soil layers were not shuffled any more and the accumulated residue on the surface may have effects on N transformations. In the first few years of using ZT, many farmers tended to use higher N rates and some researchers agreed with this practice (Angas, et al., 2006). No study on interaction of tillage with N has been conducted in safflower.

Crop rotation has a substantial influence on sustainability of any farming systems. It is generally accepted that legumes in rotation with cereals are beneficial. A long-term rotation trial conducted in Lebanon by the author confirmed these benefits in terms of barley grain and seed yield increase, and also showed the beneficial effect of safflower besides legumes (Yau, 2005). Yield increase of cereal crops after safflower was reported in areas outside the Mediterranean as well (Miller et al., 2002; Suleimenov et al., 2004; Krupinsky et al., 2004). However, the effect of previous crops on safflower performance is not known. Based on experience on other crops, it is expected that continuous safflower will be unsustainable. Latest results on barley and chickpea indicated that lower yield maybe obtained just after one year of growing the same crop (Yau, 2008).

The objective of this study was to evaluate conservation tillage, the interaction of tillage with N supply, and rotation on safflower performance since no study has been reported.

Materials and Methods

The rainfed field experiments were conducted in 2005-06 and 2006-07 at the Agricultural Research and Educational Centre (33° 56' N, 36° 05' E, and 995 m a.s.l.) of the American University of Beirut in the semi-arid northern Bekaa Valley of Lebanon, which has a cool Mediterranean climate. The long-term annual precipitation of the site is 513 mm, 58% of which falls in December, January and February. Rainfall was 480 mm for 2005-06, but was only 432 mm for 2006-07. The long-term mean annual temperature is 13.9 °C, with a mean monthly maximum and minimum of 31.7 °C in July and -4.8 °C in February, respectively. The frost-free period lasts from mid-April to mid-November. The soil is an alkaline (pH 8.0), clayey, Vertic Xerochrept formed from fine textured alluvium derived from limestone.

There were 2 factors with 4 replications in both experiments. The first factor was tillage with 3 treatments: conventional (CT), minimum (MT), and no tillage (NT). Conventional tillage consisted on one ploughing in early Oct by disc, followed by one disc-cultivation in late Oct and one grading. In MT, there was one disc-cultivation in late Oct. No tillage was carried out for NT. In 2005-06, barley and chickpea, besides safflower, were also planted in the experiment, but only safflower results are reported here. The experiment was laid out in a strip-plot design. The second factor was nitrogen: 0 and 40 kg N/ha as ammonium sulphate broadcast on Dec 16. Subplots of N were randomly assigned within the main plots of tillage. Plot size was 14m x 6m for main plots and 14m x 3m for subplots. In 2006-07, the second factor was rotation: safflower grown after a previous crop of barley, chickpea or safflower. The experiment was in a strip-plot design. Tillage was in rows and previous crop in columns. Plot size was 4.5m x 6m.

The 2005-06 experiment was conducted on a field from which a previous conventionally tilled crop of oat was harvested. The averaged content of soil mineral N in the 0-40 cm layer was 5.1 mg kg^{-1}. The 2006-07 experiment was carried out on the exact site that the 2005-06 experiment was conducted, with the tillage treatments following the same randomization. Thus the NT treatment was under zero tillage for the second year.

Seeds were sown with an experimental no-till drill in mid-Nov. Glyphosate (Roundup) was sprayed to all plots before or few days after sowing to kill germinated volunteer oat and weeds. In early spring, selective herbicide was sprayed to control monocot weeds. Aphidcide was sprayed in May/June to control aphids. In 2006-07, 60 kg N/ha as ammonium sulphate was broadcast to all plots.

Data on crop growth and dry-matter yield, soil moisture, and weed infestation were collected. In February, seedling number and vigour were recorded. In March, data on weed number and dry weight were collected. Other traits measured included dates of flowering, plant height at different growth stages, shoot dry weight at flowering and at maturity, and seed yield. For dry weight measurement, plants from three $0.25m^2$ random quadrates were cut at ground level, dried at 80°C for 24 hr, and the dry weight measured. A small-plot thresher was used for threshing. Straw yield was calculated by subtracting seed yield from shoot dry matter yield. Harvest index was calculated as a percentage of seed over dry matter yield. In 2005-06, soil moisture was measured by using a TDR meter at two depths (25cm and 50 cm) on 5 dates: Mar 31, April 21, May 19, June 15, and August 16.

The GenStat package (Version 6) was used to perform the statistical analysis. Data collected in 2005-06 were analysed as a split-plot design. The analysis for strip-plot design was applied on the 2006-07 data. The general analysis of variance program was used to do the combined analysis on tillage effects over years.

Results

Tillage by year interaction was significant for harvest index and days to flowering, but not significant for seed and straw yield, dry weight at flowering, and plant height at maturity. Harvest index was higher in 2005-06 than in 2006-07 under both CT and NT, but there was no difference under MT. Time of flowering in 2006-07 were similar under the three tillage treatments, but NT was 3 days later in flowering than CT and MT in 2005-06.

Averaged over the two years, NT gave the highest seed and straw yields, which were higher than that under MT (Table 1). There was no significant difference in harvest index and time of flowering between tillage treatments. Dry weight at flowering and plant height at maturity were higher under CT and NT than under MT. There were no differences in plants/m^2, plant height, and crop dry weight among the three tillage practices in the early vegetative stage, but there were more weeds and weed biomass under MT (149/m^2 and 98 g/m^2) than under CT (50/m^2 and 35 g/m^2) and NT (50/m^2 and 48 g/m^2).

Regarding soil moisture data collected in 2005-06, there were no significant differences between tillage practices in each of the five sampling dates. The combined analysis again showed that tillage had no significant effect, but there were significant differences between the sampling dates.

Table 1. Mean seed yield and five other agronomic characters under the three tillage practices.

Tillage	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Days to flowering (fr Apr 1)	Dry wt. at flowering (kg/ha)	Plant ht. at maturity (cm)
CT	2290	8850	19.7	70	7710	81
MT	1780	7190	19.2	70	5970	71
NT	2430	9510	19.3	71	8070	80
Mean	2160	8520	19.4	70	7250	77
L.s.d.	669	1660	ns	ns	902	8.6

In 2005-06, there was no tillage by N interaction in grain and straw yield, harvest index, days to flowering and plant height at maturity, but interaction was significant for dry weight at flowering. Under 40 N kg/ha, NT gave higher dry weight at flowering than CT and MT, but there was no significant difference among tillage practices when no N was applied (Fig. 1). Under NT and MT, dry weight at flowering increased with N fertilization, but there was no response in CT.

N treatments had no significant effect on grain and straw yields (Table 2). However, application of N reduced the harvest index, led to earlier flowering, and increased dry weight at flowering and plant height at maturity.

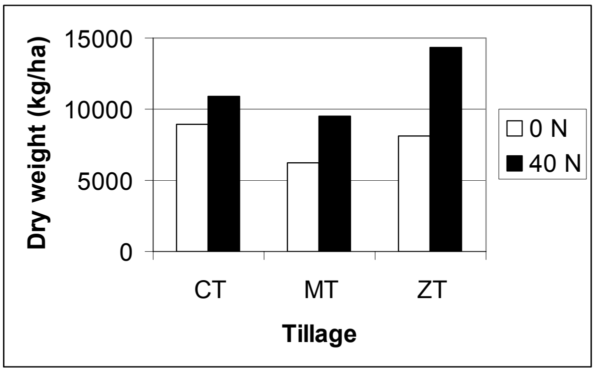

Figure 1. Dry weight at flowering under the three tillage practices and the two N fertilization rates. (l.s.d. 5 % = 2529; = 2166 in same tillage)

Table 2. Seed yield and five other agronomic characters under the two N treatments in 2005-06.

N treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Days to flowering (fr Apr 1)	Dry wt. at flowering (kg/ha)	Plant ht. at maturity (cm)
0 kg/ha	3070	9650	24	67	7780	83
40 kg/ha	2820	10970	20	65	11600	91
Mean	2950	10310	22	66	9690	87
L.s.d.	ns	ns	2.6	1.1	1251	5.0

The 2006-07 experiment did not detect any significant tillage by rotation interaction in safflower seed and straw yield, harvest index, days to flowering, dry weight at flowering and plant height at maturity. Similarly, rotation did not have any effect on these traits (data not presented), although safflower grown after safflower had less vigour, shorter in height, and lower dry weight during the early vegetative stage, and shorter height at flowering than safflower grown after chickpea and barley. Weed numbers and dry matter were higher in safflower after safflower than after barley and chickpea.

Discussion

This study showed that safflower is suitable for growing under NT as CT did not give higher yield than NT and there was no tillage by year interaction. This result was different from those reported on barley and chickpea conducted at the same site, in which inconsistent performance of NT versus CT was obtained (Yau, 2008). This result was also different from those collected on experiments conducted in Morocco where the no-till system gave better wheat grain yield than the conventional system (Mrabet, 2008). Unfortunately the report (Mrabet, 2008) does not clearly specify the differences between the systems besides tillage. It seems that the no-till system there involved earlier sowing than the conventional system, and it was the earlier seed emergence that led to the higher grain yield of the no-till system.

The absence of tillage by N interaction on grain yield suggests that N recommendation obtained under CT is applicable in NT as well. Result of the study also confirms the earlier findings by Yau and Ryan (2003) and Yau and Nimah (2005) that safflower has no yield response to N application after fertilized crops. The reason of the no response to N application can be explained by the fact that safflower has deeper roots which can take up nutrients and moisture that are unavailable to the cereals and other crops with shorter roots. However, the finding that N application led to higher dry matter yield at flowering but a lower harvest index at maturity strongly suggested that N fertilization led to a high dry matter production which led to earlier depletion of soil moisture and consequently lower harvest index.

In this study, previous crops had no differential effect on safflower performance though safflower after safflower led to less early growth vigour right after emergence. This finding was in contrast to the results of barley and chickpea collected in the same site, in which barley yielded poorer after a crop of barley than after chickpea or safflower, and chickpea gave the lowest yield after a crop of chickpea (Yau, 2008). It is speculated that as the deep-rooted safflower is able to take up water and nutrient from deeper soil layers, its seed yield is less dependent on early vegetative growth. Besides, since safflower has a much longer growing period than barley and chickpea, poorer early growth may be compensated in the later part of the life cycle. Anyway, since previous crops had no differential effect on safflower performance and since safflower can increase the seed yield of the following cereal crops (Miller et al., 2002; Krupinsky et al., 2004; Suleimenov et al., 2004; Yau, 2005), it appears clearer that cereal/safflower is a viable rotation.

Acknowledgements
Research was conducted under the financial support of the Lebanese National Council for Scientific Research (LNCSR) and the University Research Board (URB) of the American University of Beirut. Thanks also go to Diana Abu-Eid and Nicolas Haddad for technical assistance.

References

Angas, P., Lampurlanes L. and Cantero-martinez, C. 2006. Tillage and N fertilization effects on N dynamics and barley yield under semiarid Mediterranean conditions. Soil & Till. Res. 87: 59-71.

Hadjichristodoulou, A., 1985. Variety, seeding date and seed rate trials of safflower in Cyprus. Technical Bulletin 63, Agricultural Research Institute, Nicosia.

Krupinsky J.M., Tanaka D.L., Lares M.T, and Merrill S.D. 2004. Leaf spot diseases of barley and spring wheat as influenced by preceding crops. Agronomy Journal 96: 259-266.

Lal, R. 2007. Constraints to adopting no-till farming in developing countries. Soil & Till. Res. 94: 1-3.

Mrabet, R. 2008. No-till practices in Morocco. In Goddard, T., Zoebisch, M.A., Gan, Y.T., Ellis, W., Watson, A. And Sombatpanit, S. (eds) No-Till Farming Systems. Special Publication No. 3, World Association of Soil and Water Conservation, Bangkok, pp. 393-412.

Miller P.R., Waddington J., McDonald C.L., and Derksen D.A. (2002) Cropping sequence affects wheat productivity on the semiarid northern Great Plains. Canadian Journal of Plant Science 82: 307-318.

Pala M. and Beg A. 1997. Agronomic assessment of safflower germplasm and research priorities in the West Asia and North Africa region. Proc. of 4th International Safflower Conference, Bari, 1997, 86-90.

Suleimenov M.K., Akhmetov K.A., Kaskarbayev J.A., Khasanova F., Kireyev A., Martynova Kyrgyz L.L., and Pala M. (2004) Developments in tillage and cropping systems in Central Asia. In Ryan J., Vlek P., and Paroda R. (eds.) Agriculture in Central Asia: Research for Development. ICARDA, Aleppo, Syria. Pp. 188-211.

Tanaka, D.L., and S.D. Merrill. 1998. Deep-rooted safflower cuts fertilizer losses. http://www.ars.usda.gov/is/AR/archive/apr98/saff0498.htm

Yau S.K., Pala M., and Nassar A. (1999). Safflower (Carthamus tinctorius) production and research in Lebanon. Sesame and Safflower Newsletter 14: 97-102.

Yau, S.K. and Ryan, J. (2003) Potential of safflower to mitigate nitrate leaching. In Abstracts (CD format) of the Annual Meeting of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Denver, USA, November 2-6, 2003.

Yau S.K. (2004). Yield, agronomic performance and economics of safflower in comparison with other rainfed crops in a semi-arid, high-elevation Mediterranean environment. Expt. Agric. 40: 453-462.

Yau, S.K. 2005. Yield increase of barley following safflower in a cool, semi-arid Mediterranean area. In Proceedings of the 6th International Safflower Conference, Istanbul, Turkey, June 6-10, 2005, p. 92-97.

Yau, S.K. and Nimah, M.N. (2005) Potential of safflower to mitigate nitrate leaching under irrigation. In Abstracts (CD format) of the International Annual Meeting of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Salt Lake City, USA, Nov 6-10, 2005.

Yau, S.K. 2008. Tillage and crop rotation – differential effects on barley and chickpea. In Abstracts of 5th International Crop Science Congress, Jeju, South Korea, April 13-18, 2008, p. 93.