MAIN ADDRESS

MODERN ASPECTS OF SUNFLOWER CULTIVATION TECHNIQUES

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PREMISE

The world-wide cultivated area of sunflower increased fromu 6.238 million hectares in 1948-50 to 16.288 million hectares in 1990. During the same period of time yield per hectare rose from 0.603 T/ha to 1.355 T/ha, representing an increase of 135%. A number of factors contributed to this achievement, in varying proportions in different parts of the world: genetic improvement, improved agronomic techniques, and in addition greater knowledge of plant physiology.

Use of hybrids, the first of which were introduced in the early 'Seventies, provided the initial thrust towards crop improvement. Hybrids were endowed with greater production potential and were made resistant to many major diseases; consequently, cultivated area increased by 2.550 million hectares in the decade stretching from 1970 to 1980, and by another 4.0 million hectares in the following decade (Tab.1).

Throughout Europe (excluding the ex-USSR), there occurred a corresponding expansion, with a rise from 869 thousand hectares during the decade 1950-60, to 3.139 million hectares in the decade 1980-90. Unit yield rose during the same period of time from 0.989 T/ha to 1.610 T/ha, with a percent increase of 61.43%.

Europe is still today the continent where unit yields are highest. At the tip of this evolutionary process there stands France, where yields rose from 1.345 T/ha in the decade 1950/60, (over an area of 4000 hectares), to 2.253 T/ha in the five-year period from 1985-90 (over a surface that in the meantime had expanded to an area of 936,166 ha, with a maximum extension of 1,170,000 in 1990). In this development, percent increase is close to 100%. Factors contributing to progress include both further achievements in the field of genetic improvement and also the fact that crop expansion in France took place above all in the most favorable environments.

If one examines productivity of hybrids listed in France's national seed catalogue during the period 1980-1990 (Table 2), it can be observed that genetic improvement allowed a 1.28% yearly increase in production compared to the control hybrid "Mirasol". During the same period in France, increase in cultivated area was paralleled by an increase in national mean yield of 0.436 t/ha.

Furthermore, even in other parts of the world, beneficial effects were noted deriving from progress in sectors exercising considerable influence over production, such as creation and subsequent availability of hybrids with a more precisely defined cycle, with more limited height, greater resistance to lodging, greater environmental adaptability and disease resistance. All of these factors contributed to better application and successful utilization of discoveries in the field of agronomic techniques.

Today sunflower cultivation is spread over such an extensive area and forms part of such a widely diverging variety of types of agriculture and environment, that it has become extremely difficult to establish valid general norms of cultivation techniques that can be equally effective throughout all areas.

Extension of sunflower area is certainly vastly inferior to that of autumn-winter cereals, but it is greater than that of summer cereals, whose needs most closely approximate sunflower requirements. On account of its considerable extension, the sunflower area today involves both hot arid climates and also temperate climates. In these two very different conditions, factors of humidity and temperature, though remaining within the framework of reciprocal compensation as regards crop requirements, are widely diverging in absolute terms.

Given the broad sprectrum of variation depicted above, it becomes difficult to lay down universally valid guidelines based on agronomic techniques that form part of modern crop management systems. Discussion will therefore be restricted to indicating measures designed to meet plant requirements in the environments best suited to the crop, also outlining a synthesis of results of recent research.

ROTATION

Sunflower is a classic plant for use in the succession of crops. Extent and composition of residue left on the ground after harvest constitutes an excellent contribution to the following crop. Thus achene production of 25 q per hectare leaves an average residue of ogranic substance on the ground amounting to roughly 50 Kg of N, 25 Kg of P_2O_5 and 225 Kg of K20.

It should be added that in comparison to other spring-sown crops, sunflower presents a shorter cycle, which allows the ground to be cleared relatively early and, so that it can be carefully prepared for the following crop.

In order to avoid problems linked to spread of disease, sunflower should ideally not be resown on the same ground until at least a 5-year interval has elapsed. Unfortunately, however, economic motives lead farmers to resort to shorter periods of rotation, the phytopathological consequences of which can readily be imagined. In this oilseed crop as in other crops, proper succession of crops has the effect of reducing competitivity of weeds. Broom-rape (Orobanche sp) can be taken as an example. By increasing the interval between two successive sunflower crops from 2 to 5 years, incidence of this parasitic weed dropped from close to 6 individuals per plant to less than 1 (Malykin et al., 1973). When broomrape is present, it is essential to introduce autumn-winter cereals into the succession of crops, to restrict both diffusion and development of the weed.

Another important issue, where rotation is concerned, is that several weeds which are typically extremely difficult to bring under control can in fact be more effectively restrained if rotation includes sunflower, since this means that a greater range of a.i. endowed with specific selectivity becomes available to combat these weeds. For instance, rhizome sorghum halepense in maize-growing environments can be effectively controlled if sunflower (or soya) is introduced into the rotation scheme, by means of post-emergence specific graminicide treatment. On the other hand, certain dychotiledons that are hard to control in sunflower (Abutilon theophrasti, Chenopodium album, Convolvulus arvensis, etc.) prove to be easier to attack in maize.

When dealing with rotation, it is however necessary to avoid problems deriving from use of herbicides applied to crops preceding sunflower. Herbicides may persist in soil and cause phytotoxic phenomena of varying intensity on crops. The classic example is atrazine, residues of which negatively affected plant biometric development, achene production and achene oil content (Miele et al., 1974). Similarly, clorsulfuron may damage over 30% of sunflower plants when soil pH is 7.5 and organic substance content is 3%, while no harmful effects were observed when the reaction was roughly one unit lower (ph 6.6) (Peterson et al., 1984).

TILLAGE

As is well known, tillage consists of a complex of mechanical operations carried out on soil in order to make the ground as "suitable" as possible to host a crop. In order to ensure that the medium can act as a suitable host, physical characteristics and water availability are the chief factors on which operations focus, though the various manipulations the soil may undergo also frequently affect chemical and nutritional properties.

Soil preparation for a spring-summer cycle crop such as sunflower aims to establish the best relation between type of intervention on soil and typical soil characteristics, in order to increase soil water retention capacity. On the other hand, one cannot escape the observation that the role and direct or indirect effects of various modes of tillage may differ substantially, not only as a result of the type of ground under preparation, but also on account of weather conditions during crop growth, position of this particular crop in the succession of crops, and tillage previously carried out for the preceding crop.

Research on this issue where sunflower is concerned has not been widely carried out. Basically, the tendency is to indicate the optimal conditions constituting the target to be achieved, rather than specifying technical means by which the target should be attained in the different operative conditions under which the crop is grown.

Bibliography on the topic shows only a limited number of references to research on the most appropriate soil prepraration techniques. Furthermore, the research in question refers almost exclusively to experiences in Mediterranean environments, comparing traditional tillage with alternative techniques of minimal and/or no-tillage (Giraldez et al., 1986; Ballestero and Guerrero, 1986; Mesa Garcia et al., 1986; Valera Gil, 1986). Results obtained during 1985-86 in the Iberian peninsula in a dry climate on soils with high expandable clay soils appear to show that mean yields obtained from different types of tillage are substantially indifferent.

Results obtained by Sin et al. (1987) during 15 years of experimentation on different types of soil in Roumania suggest that it is possible to carry out tillage to a depth of 20-30cm, followed by minimum tillage in alternate years, without any substantial effect on crop production.

Deibert and Utter (1989) experimented over a two-year period on clay soils (Vertic Haplaquoll) in North Dakota (USA), showing that reduced tillage (fall sweep, fall intertill and no-tillage) combined with adequate weed control enables production to be obtained analogous to that obtained with early or late sunflower hybrids grown on traditionally tilled soil (fall plough).

By contrast, investigation into this issue over the last few years in several typical environments of helianthus cultivation in Central Italy (Archetti et al., 1983; Bonari and Mazzoncini, 1986; Bonari et al., 1987a; Bonari, 1988) seems to provide some interesting suggestions concerning the possibility of adopting for this species modes of tillage alternative to traditional deep ploughing.

Experimental results available to date reflect experiments performed over a period of roughly five years by the Agronomy Institutes of the Universities of Perugia and Pisa. Research was carried out in dryland cultivation and in different pedological situations: on medium clay loam (Perugia) and tendentially silty soil (Pisa), in order to compare minimum tillage with traditional tillage (Bonari, 1988).

During the experiments, minimum tillage always gave lower mean yields compared to ploughing, independently of the depth of ploughing. Expressed as a mean over the years, production of 2.71 and 2.79 t/ha was obtained in Perugia for minimal tillage and ploughing respectively, while in Pisa the corresponding values were 2.41 and 2.99 t/ha. The negative results deriving from minimal tillage in this case seem to be more accentuated in silty soils than in tendentially clayey soils, and often seem to be linked not only to the less satisfactory physical conditions in the topsoil, but also to the lesser "efficiency" of minimum tillage in achieving weed control.

Furthermore, using results derived from the same trial, a comparison was made of data pertaining to results obtained at different depths of ploughing. Although so far no definitive conclusions can be drawn, these data strongly suggest that at least in most years of production, reduced tillage (25-30 cm) can lead to similar or even superior results compared to deep ploughing (roughly 50 cm). Results of this kind were indeed observed on various types of soil during years characterized by normal or limited summer rainfall, and in all cases better seedling emergence was observed with lighter tillage together with less difficulty in getting the crop established, above all in silt-rich soils.

SOWING: DATES AND MANNER

Since sunflower cultivation takes place at a variety of different latitudes, altitudes and climates, naturally both its cycle and stages undergo modification and require corresponding modification in sowing time.

If drought occurs only during the summer season, as is the case in the Mediterranean climate, then date of sowing can correct unfavorable climatic conditions if it is brought forward to some extent in relation to seasonal rainfall of the crop environment.

Table 3 provides an illustration of the most common sowing dates in different sunflower cultivation environments:

TABLE 3: Recommended sowing dates in selected countries

COUNTRY	MONTHS
India	
North	July and October
South	April and November
Iraq	April-May
Pakistan	February
Bangladesh	August and January
Africa	
North	March
Central	June
South	December-January
USA	April-May
Canada	March and November
Brazil	August
Argentina	October
Venezuela	October and November
C.I.S. (ex.USSR)	
East	March
West	April (or immediately following date on which spring cereals are sown)
Europe	March and April
Australia	
North-East	January
South-East	September
West	May

In certain tropical and subtropical areas with a hot humid climate, variation in sowing date allows avoidance of some types of disease, as for instance, in Venezuela and Mozambique, where it was possible to grow sunflower in the dry season. The reason lies in the fact that in tropical or subtropical conditions characterized by a hot humid climate, sunflower is susceptible to being attacked by pathogenic fungi which prevent or severely limit its cultivation, such as: Alternaria sspp., Macrophomina sspp., Erwinia carotovora, Pseudomonas sspp. By sowing sunflower at the end of the rainy season, disease can be bypassed and if the crop is supported by irrigation, high production can be achieved.

In certain areas of southern Europe sowing date can be brought forward to the winter period. There are a number of Mediterranean-type environments in which spring-sown crops are affected by irregularity and variability of rainfall during the rainy period, with ensuing water deficiency during the flowering stage, which is the most critical period of crop water requirements. It is frequent in such environments for water deficiency to be accompanied by high temperatures and hot winds, affecting physiological maturation and leading to marked reduction in seed production and oil content.

The problem of irregular rainfall can be overcome by ensuring that the plant cycle occurs within a period in which rainfall is sufficient to satisfy plant water requirements. With this target in mind, a number of researchers: Gimeno et al (1985), Hadjichristodoulou (1987), Boujghagh (1990) in Spain, Greece and Morocco respectively performed experiments with sowing dates brought forward to the winter period (November-December). Results of these trials indicate that in Mediterranean environments winter sowing is a possibility. In all cases, production obtained through sowing at the above winter dates was decidedly greater compared to that obtainable with spring sowing.

In these conditions, when sowing dates are shifted up from November to March, yield undergoes progressive decrease (Robinson 1970; Alessi et al., 1977; Dedeo, 1975; Gimeno, 1985; Boujghagh, 1990).

Low winter temperatures may slow down plant development and determine appearance of lateral ramifications in some genotypes.

On the basis of results obtained by Boujghagh (1990), medium-early varieties appear to adapt more readily to winter sowing: given that they have a slower developmental cycle, they succeed in reaching the flower-bud-flowering stage as winter comes to end.

Early varieties seem to adapt better to January sowing, as their early flowering enables them to escape the effects of high summer temperatures and accompanying water deficit.

The most desirable ideotype for winter sowing is that of a plant which is indifferent from the point of view of the photoperiod, capable of withstanding low temperatures in initial growth stages, characterized by initial slow development of the above-ground part in which growth is favored, extensive and deep-reaching development of a robust root apparatus, free from the phenomenon of secondary ramification, capable of reaching the tillering stage and forming the flower bud at the end of winter. This genotype must be highly self-compatible and capable of achieving the phase of seed filling and seed ripening in late spring and early summer, i.e. in a period characterized by rising temperatures and decreasing water availability.

In order to obtain genotypes suitable for winter sowing, agronomic techniques will necessarily have to be updated. For it is inconceivable that all techniques worked out so far to meet the requirements of a spring-sown crop with a spring-summer cycle can simply be extrapolated unchanged to a crop with winter-spring cycle. Particular attention will have to be paid to weed control in the first stage of crop development, as well as control of gramineous grasses and microtherm cotyledons, and to control of late weed development in the spring-summer period. It will prove vital to have an effective herbicide available in the post-emergence period for control of late weeds. Nitrogen fertilization will also have to be revised, in particular when used as top dressing. Investment will have to be adapted to the new requirements and new genotypes. Last but not least, disease and parasite control will have to be carried out in such a manner as to allow the plant to attain its maximum production potential. All above problems will have to be resolved by crop management techniques and by genetic improvement in order to allow greater diffusion of this new possibility that is opening up for sunflower cultivation in suitable environments.

In temperate climates utilization of sunflower as a second crop offers another interesting possibility, taking into account that the period from sowing to emergence and then from emergence to flowering decreases with shift from early crops to late varieties.

Sunflower is classified as a day neutral or photoindifferent (Allard and Garner, 1940; Pinthus, 1959; Kernik, 1961) crop. Therefore the shortening of the period from emergence to anthesis observable with late sowing is due not so much to variation in the photoperiod, as, rather, to increase in temperature gradient (Robinson et al., 1967; Robinson, 1971; Unger, 1980). When sown as an intercalary crop, this oilseed crop has high temperatures available from the start, which allow rapid growth provided that an adequate water supply is also available. Consequently, plants present more rapid and more extensive leaf development, and thus photosynthesize earlier. Furthermore, leaf formation and growth is also more rapid at higher temperatures than would be optimal for the NAR (Net Assimilation Rate). The reason, according to Warren (1966), is that optimal growth temperature is that which determines greatest speed of leaf development rather than that which maximizes the NAR itself.

When late sowing is carried out, sunflower may face elevated daytime temperatures. These high temperatures are better tolerated during the vegetative stage compared to the reproductive stage (Vranceanu, 1974). It should also be noted that when sowing follows harvest of an autumn-winter cereal, thermal excesses no longer represent a serious problem during the period of physiological maturation, given that maturation in effect takes place during a period in which temperatures tend to decline or even become deficient.

When sunflower is sown as an intercalary-crop, on the other hand, the more serious problems consist in satisfying water requirements. If water is scarce at the outset of the vegetative stage, only modest growth of leaf apparatus takes place, as a result of reduction in number of leaves and low leaf area increase. But when water shortage occurs towards the end of the cycle, causing leaf water potential to reach approximately minus 15 bar (Merrien et al., 1981 b), decrease in photosynthesizing area is observed, deriving from accelerated senescence and death of the leaf lamina. The importance of these observations resides in the fact that in sunflower, decrease in yield is closely connected with reduction in overall leaf apparatus rather than with leaf surface unit activity. It must be kept in mind, however, that even though water stress is manifested first of all, and most obviously, in leaves, nevertheless all other plant organs are equally subject to water stress through transpiration (Cruiziat and Bodet, 1974). This is confirmed by noting that when the leaf apparatus is artificially reduced, plant water loss remains practically unchanged (Blanchet and Gelfi, 1978), since under strong transpiration the water reserve present in other organs and even in roots may be affected.

Sunflower cultivation as a second crop is possible in an environment with a temperate-hot climate, with complete or partial satisfaction of water requirements (Salera et al., 1988; Baldini et al., 1990).

Results obtained show that in the Italian environment highest production can be obtained when sowing takes place before end of June (following barley or silo-wheat), using early or medium-early varieties. The period ranging from emergence to flowering appears to be directly influenced by temperature: in experiments performed in Pisa, plants began to flower only after reaching the specific thermal level (1030 - 1065 °C).

Highest oil and seed production per ha and per plant is obtained when sowing is carried out in the second ten-day period of June. This enables the crop to make use of a longer period of flowering-physiological maturation (45 days on average), with ensuing production of a high number of achenes per plant (1010), and more prolonged leaf assimilation activity.

If sowing is carried out between in the third ten-day period of June, the above-mentioned phenological stage is shown to be shortened (average duration 35 days), which in its turn reduces achene oil accumulation. When sowing is planned to follow wheat harvest, selection of variety is of essential importance, for certain varieties respond to shortening of this phenostage by pronounced decrease in yield.

For instance, in experiments performed in Pisa the early cultivar "CERFLOR" was able to provide elevated H.I. (Harvest Index) (0.34 and 0.32) with late sowing dates. The elevated H.I. enables this hybrid to obtain excellent production levels and also leads to greater efficiency during the seed filling stage, by improving the mechanism of redistribution of products assimilated by plant organs (such as stem and leaves).

In every case complete satisfaction of plant water requirements appears essential for achievement of high production.

MANNER OF SOWING: INVESTMENT AND INTER-ROW SPACING

The manner of sowing represents another aspect of crop management systems that is of particular interest, given that it incorporates a number of fundamental principles. Firstly, for purposes of proper "management" of the population of individuals of which the crop is constituted, the manner of sowing must aim to ensure that the crop achieves highest possible utilization of incident radiation. Secondly, it is important to bear in mind that sowing density - and above all planting geometry - can affect other crop management techniques that a farmer may wish to adopt (kind of seeding and harvesting machines to be adopted, tilling and soil preparation processes to be carried out in succession, weed control, and so forth).

Sunflower crop production is defined by the product of the following three components:

a) number of heads per hectare,
b) number of seeds per head,
c) mean weight of seed.

Given that the cultivated sunflower produces only one head per plant, the number of plants per surface unit forms the most important production parameter. Consequently, this parameter, together with various environmental factors (such as climate, soil type, fungus attacks, animal invasions), strongly influences the other two components.

Under conditions of low investment, sunflower tends to increase mean achene weight and number of achenes per head, while under conditions of low investment, reduction in achene weight and number of achenes per head is observed, accompanied by an increase in oil content per plant. It follows that since production is given by the product of the three components, production remains relatively constant over a wide range of investment.

Indeed it has been widely documented through scientific research on sunflower that this crop is capable of adapting to considerable plant density without appreciable variation in achene production per surface unit (Longo and Restuccia, 1975; Pacucci and Martignao, 1975; Miller and Fick, 1978; Mathers and Steward, 1981; Guiducci, 1972; Monotti et al., 1982; Flengmark, 1984; Holt and Campbell, 1984).

In other cases, on the other hand, researchers have provided indication that optimal density lies within a much more restricted range, at times with no more than a few individuals per surface unit (Curotti and Rosania, 1971; Alessi et al., 1977; Da Silva and Schmit, 1985). Success with medium densities of 35-50,000 plants per hectare was also reported (Monotti, 1973; Longo and Restuccia, 1975; Curotti et al., 1977; Tarantino and Alba, 1978; Laureti, 1981; Da Silva and Schmit, 1985;Stanojevic, 1985; Zaffaroni and Schneiter, 1985; Cuocolo, 1987). In some cases even greater investments were recommended (Massey, 1971; Zubriski and Zimmerman, 1974; Avila et al., 1979; Daka and Agrawal, 1981; Monotti et al., 1982; Vannozzi et al., 1985; Vannozzi et al., 1987, Baldini et al., 1988; Rao and Saran, 1991). A comparative synthesis of the most significant production results obtained in Italy in recent research, with reference to one variety that was common to all trials, is illustrated in Figure 1.

The different interpretations of the results of crop density studies as put forward by the various researchers seem to suggest that the effect in question is not only masked to varying extents by environmental parameters, *including nature of the soil*, temperature and rainfall, but is also frequently linked to other aspects of crop management techniques, such as irrigation and mineral nutrition. Furthermore, while in some cases crop density seemed to bear no significant relation to stock varieties examined, in other cases the distinct impression was gained that morphological characteristics of the given cultivar on which tests were performed played a crucial role in determining whether sowing density could be increased. Results described in the extensive literature on this subject show no overall agreement. Marked differences between regions and nations can be observed at times. In the many environments where differences in production between different investment levels were recorded, the productions obtained were in fact fairly low, suggesting that factors other than the mere question of investment contributed to limiting production. Consequently, even the lowest investments were capable of giving the highest production.

This is confirmed by the work of Blanchet et al. (1988): on account of its powerful and deep-reaching root system, sunflower is capable of responding to high investments only in the presence of excellent nitrogen and water supply, which has to be provided in order to ensure that competition for nutritional elements does not limit production per plant.

Genetic improvement has also been of aid in the search for optimum plant density, through creation of hybrids endowed with good resistance to lodging and of short stature (Figure 2).

Variation in investment can influence oil production per plant and oil cake characteristics (Graph 1, Table 4). Experiments conducted in Pisa showed that with increasing investment, oil content per plant increased from 2 - 2.5% according to the cultivar utilized (Romsun HS 90 and Stromboli).

Though this vast array of considerations seems to indicate that no definitive and generalizable mean optimum investment can yet be stated for sunflower, we nevertheless believe that the best recommendation is that sowing density should be in harmony with the trophic and environmental characteristics expected to be effectively available to the crop during the course of its cycle (Zaffaroni and Schneiter, 1991). Any slight error in forecasting should not be a cause for serious concern for the farmer, since most currently available varieties of sunflower appear to be able to guarantee fairly constant mean yields even under considerable crop density.

These observations are also based on the assumption that the operator is able to provide irrigation to supplement natural water reserves during the second stage of the crop cycle. It should be kept in mind, however, that adequate achene production per surface unit (high number of achenes per sq.m.) always requires achievement of adequate L.A.I values (leaf area per ground surface unit). Moreover, one should not forget that in these conditions competition for water supply between plants may be further intensified, and in our view this remains the main factor limiting indiscriminate increase in crop density.

These conditions pose less of a problem if shorter hybrid varieties are use, whose stalk has good resistance to breakage, especially if sowing is carried out without excessive delay and a certain amount of irrigation support can be provided during the achene filling stage.

Agronomic research into optimum sunflower investment has also given careful consideration to the role played by inter-row spacing. Early studies on this question concentrated on investigating the possibility of narrow inter-row spacing, with rows spaced at 90 - 110 cm. But the densities adopted proved to be too low, and the varieties adopted are now considered outdated (Curotti and Rosania, 1971; Pacucci and Martignano, 1975; Alessi et al., 1977). But experimentation with narrow inter-row spacing has been taken up again by a number of researchers (Huang and Hoes, 1980; Robinson et al., 1980; Guiducci, 1982; Kirton, 1985; Da Silva and Schmidt, 1985; Vannozzi et al., 1987; Zaffaroni and Schneiter, 1991).

Originally, the whole question of inter-row spacing was at least in part linked to problems concerning use of mechanical cultivators, and above all combine harvesters. Now that improved mechanical equipment for sunflower harvesting is able to operate on spaces between rows much narrower than the traditional 70 - 75cm., research on the issue of narrow or optimal inter-row spacing can focus on other aspects of crop development.

From a physiological point of view, it appears that closely spaced rows allow better distribution of plants over the ground, thereby allowing optimal light interception by each individual. Better utilization of soil water content and nutritional elements is also achieved. Intuitively, at least in areas where water availability does not constitute a severe limiting factor, better light interception at narrow row spacing could perhaps also allow increase in number of plants per surface unit, without appreciable variation in plant spacing along rows if compared to traditional schemes with wide inter-row spacing.

In trials carried out several years ago experimenting with different inter-row spacings and different investment densities, no appreciable differences in crop production capacity were recorded (Curotti and Rosania, 1971; Monotti, 1973). Subsequently, other researchers pointed out that width of inter-row spacing interacted with number of plants per surface unit, and at times also with morphological characteristics of the varieties tests (Pacucci and Martignano, 1975; Alessi et al., 1977). Results of this research suggested that narrower spaces between rows can lead to better production precisely on account of the higher investments, using relatively short varieties.

More recently, investigation into optimum planting patterns underwent further development, focusing on utilization of more modern hybrids (Da Silva and Schmidt, 1986; Vannozzi et al., 1987; Cetiom, 1987). The tendency towards increase in yield when narrow inter-row spacings are adopted was confirmed, although it could not always be linked to an appreciable increase in investment.

One of the positive aspects of reducing inter-row space is that leaves more rapidly and more completely shade the space between rows. This could lead to reduction in quantity of water lost through evaporation, allowing more efficient crop water balance, and it could also play an important role in weed control, which is particularly important in the early stages of crop development.

In environments characterized by limited water supply, narrow inter-row-spacings may thus represent an interesting technique of dryland cultivation. For if one examines the WUE formula for IPA.RICHARD 1991,

$$WUE = TE / (1 + ES/T)$$

where TE is transpiration efficiency, ES is evaporation and T transpiration, it can be observed that according to the equation, an increase in WUE can be obtained by increasing TE, in other words by increasing the ratio of formed dry matter/transpired water, or else by decreasing the denominator, in particular by decreasing ES with respect to T.

Thus by reducing inter-row-spacing, agronomical techniques make it possible to achieve reduction in soil evapotranspiration. Restricting inter-row-spacing from 70-80 cm. down to 40-50 cm. encourages rapid ground cover and greater soil shading, and under conditions of equivalent investment, it also leads to greater spacing along the row, up to values close to equidistance (Baldini et al.,1988).

Data obtained in Pisa during ten-year experimentation (Figure 3) confirm these observations. Both with tall and short hybrids (and with hybrids of short stature the phenomenon is particularly visible), maximum production was always obtained with inter-row-spacing of 40-50cm.

The above observations have underscored the importance of achieving sunflower planting patterns capable of obtaining maximum production capacity from modern hybrids, while maintaining compatibility with agronomical characteristics of the environment of cultivation. It should be borne in mind, however, that independently of the desired number of plants per surface unit and the inter-row-spacing adopted, regular spacing of plants along the row is also of extreme importance. It has been widely demonstrated that excessive distance or closeness between plants prevents plants from making complete use of the "space" available to each plant, thus accentuating negative effects of competition between individuals and leading to marked loss in yield (Remussi 1976). We cannot overemphasize how important it is for farmers to utilize highly precise and efficient seeding machines, and to carry out seeding operations with the utmost care, but it is equally vital that seed manufacturers supply agricultural operators with quality seeds from the point of view both of exact size of seed and uniformity of shape.

FERTILIZATION

Study of sunflower trophic requirements has unanimously recognized the preponderant role played by nitrogen. In general, however, research on crop nitrogen fertilization has often provided unclear results concerning amount of fertilizer to be administered and most appropriate manner of administration (Massey, 1971; Coicetal, 1972; Robinson, 1973; Zubriski and Zimmerman, 1974; Longo and Restuccia, 1975; Monotti, 1978; Vrebalov et al., 1982; Pirani, 1983; Benvenuti, 1984; Cholaky et al., 1984; Vannozzi et al., 1985 and 1987; Blanchet et al., 1986 and 1987; Zehnalek and Minar, 1987; De Giorgio et al., 1988; Bader and Rashid, 1988; Merrien et al., 1988; Sultan et al., 1988; Lozanovic and Stanojevic, 1988; Samui and Ghosh, 1988; Hera et al., 1987; Chaniara et al., 1989; De Giorgio et al., 1990; Sidhu et al., 1991; Fredeen et al., 1991). In most cases nitrogen doses above 70-100 kg/ha did not appear to be decisive, but the literature is not without cases quoting successful results obtained by lower or higher doses than these.

Given this premise, it is of considerable interest to reconsider the most recent results deriving from research into sunflower nitrogen fertilization and the way fertilization affects final yield. Different conditions of water availability also need to be taken into consideration in evaluating fertilized sunflower yield.

It is known that nitrogen nutrition plays a decisive role in sunflower growth and production above all during the stage ranging from tillering to flowering (Coic et al., 1972; Vrebalov et al., 1982). The importance of this period resides in the fact that it is linked to expansion of formed leaves and intensity of various photosynthetic processes (Radin and Boyer, 1982; Courtiade, 1983; Rawson and Turner, 1982a/b, 1983), and it is furthermore linked to differentiation of flower buds and consequently to formation of an adequate number of achenes per plant (Steer and Hocking, 1984a and 1984b; Blanchet et al., 1986). Achene number, which is a crucial feature as far as the final production result is concerned, has in its turn been shown to be closely connected to leaf area shortly before the flowering stage. It follows that adequate nitrogen absorption in early stages of the vegetative cycle is more or less indispensable for optimum development and maintenance of maximum leaf area, and consequently also for formation of a sufficient number of achenes (Palmer and Streer, 1985; Merrien, 1986).

It is to be noted, however, that nitrogen requirements during this phase do not appear to be quantitatively elevated (Blanchet et al., 1987a). High nitrogen availability during the early stages (over 60-79 kg/ha) could lead to overluxuriant vegetative growth, with the ensuing risks of excessive self-shading, lodging and greater susceptibility to water deficit. By contrast, several recent trials concerning sunflower water and mineral nutrition showed that the crop can gain access to soil nitrogen reserves without great difficulty even at considerable depth (Berengena and Henderson, 1980; Maertens and Bosch, 1981; Decau et al., 1984; Blanchet et al., 1986). This possibility of "deep" absorption, which is virtually independent of the fertilizer level adopted, was however shown to be decisive for "late" plant nutrition (when the crop needs to make adequate replacement for nutrients following strong demand by achenes for nutrient transfer during the seed filling stage). In the above-mentioned late stage, definition of adequate crop mean yield will depend above all on duration of leaf area (the ageing of which is retarded by optimum mineral nutrition, among other factors) and on plant water absorption capacity.

Given that "natural" soil nitrogen content contributes over 70% of the total quantity of this nutrient element absorbed by the crop (Merrien 1986, 1988), it can readily be seen why the real utilization coefficient of applied fertilizer is particularly low in sunflower (estimated at approximately 20-30% compared to 60% in wheat). It also becomes equally clear why this crop can be considered an excellent utilizer of soil nitrogen residues.

In cases of low availability of soil nitrogen residues, however, an increase in the real nitrogen utilization coefficient is observed (Merrien et al., 1988).

Research by Hera et al. (1989) has underlined that mineralization of applied nitrogen fertilizer is correlated with increase in number of plants per ha (from 40,000 to 60,000 plants/ha), and also with irrigation. Nitrogen accumulation, total N content per plant and seed production all increase with increasing dose of applied nitrogen fertilizer, with increasing investment, and with irrigation. At higher investment, irrigation determines an increase in the real nitrogen coefficient. During the first year of application, 50.3 kg. of N out of the 120 kg N/ha administered were immobilized in the soil. Part of the fertilizer-derived nitrogen (7-12%) was utilized by the crop after being immobilized and subsequently re-mineralized.

Work by Merrien et al., 1988, has allowed the following additional observations to be made concerning sunflower nitrogen fertilization:

- Plant nitrogen absorption takes place very early;
- Maximum nitrogen utilization generally occurs during the flowering stage: in this phenological stage 50-60% of the nitrogen absorbed in the form of fertilizer is to be found in leaves. Leaves constitute an organ for transitory storage (over 40%) of total nitrogen. After flowering, there is intense redistribution of nitrogen contained in leaves and to a lesser extent in the stem towards the head and seeds.

After the flowering stage, plants generally obtain the nitrogen nutrient by utilization of nitrogen residues present in the soil.

Nitrogen deriving from fertilizer applied after flowering is well mobilized by the calathide, suggesting the possibility of improving both the 1000-achene weight and also protein content through improved late absorption.

Recent research on sunflower water and nitrogen supply has clearly shown that high nitrogen fertilization may have negative results whenever water constitutes a strongly limiting factor (since nitrogen affects both number of achenes per plant and also achene mean unit weight). Response to nitrogen fertilization is quite weak whenever water availability provided by rainfall (or by irrigation) falls below roughly 200 mm. during the crop cycle, but the response is lively when water supply is abundant (Blanchet et al., 1987).

In order to define a proper crop nitrogen fertilization program, extent of available water resources must be evaluated (whether natural or artificial). When water availability is known, it is possible to attempt to estimate probable seed yield (according to Blanchet an average requirement of roughly 10-15 mm water per quintal of achenes can be expected). Estimate of seed yield then allows total crop nitrogen requirement to be estimated (roughly 2-3 g/plant according to Merrien, 1986-1988). Approximately 1g/plant of this nitrogen (equivalent to about 60-70 kg/ha) must be absorbed before differentiation of flower buds and must be available in the first 40-50 cm. of soil.

Subsequent crop requirements in later stages of the cycle should be adequately covered by quantities of nitrogen already present in the soil, provided that the root system can reach down to sufficient depth.

In practical terms, addition of 60-80 kg/ha of nitrogen during seedbed preparation is considered by some researchers to be sufficient for the crop. Larger quantities seem to expose the plant to greater risk of lodging and cryptogams, as well as leading to lower seed oil content (Merrien, 1986; CETIOM, 1987).

In Italian environmental conditions, given the generally scant availability of nitrogen in Italian soil, it may be wise to recommend slightly higher doses (90-110 kg/ha) when average traditional investments are adopted (5-6 plants/sq.m.). In environments characterized by soils with sufficient water content, if higher investments are desired, a slight further increase in dosage may be envisioned (110-130 kg/ha).

As far as the manner of fractionation is concerned, the considerations outlined above would seem to point to desirability of early nitrogen distribution. Confirmation of this approach comes from results recently obtained in Italy (Vannozzi et al., 1986; Bonari, 1988).

Studies on phosphate and potassium fertilizer in sunflower are so far limited in number (Longo and Restuccia, 1975; Zubrisky and Zimmerman, 1974; CETIOM, 1987; Merrien, 1986; Hunter and Kochman, 1985) compared to the amount of studies on nitrogen fertilization. From results obtained to date it does not appear that there is any need for established methods of crop management (Benvenuti, 1984; CETIOM, 1987) to be updated.

Total plant phosphate uptake is 0.30-0.35 g/plant according to Merrien et al., 1986, while crop uptake is roughly 1.5-2.3 of P205 /quintal of seed, according to Benvenuti and Vannozzi,1981. Despite fluctuation in values due to potential interaction between phosphorus and nitrogen supply (Hunter and Kochman, 1985), no particular problems of a practical or technical nature seem to arise, provided that the sunflower root system reaches down to a sufficient depth. Uptake of phosphorus is restricted to roughly 40-50% of the total quantity absorbed by the crop, and it is therefore important that administration of this element be defined on the basis of reserves already present in the soil. Under conditions of rich well-endowed soil, with pH close to neutrality, it is only necessary to reintegrate the element taken up by adding roughly 60-80 kg. of phosphoric anhydride, which can be increased to 100-120 kg/ha in soils with insufficient phosphorus content.

Sunflower also absorbs a high quantity of potassium (4-4.5 g/plant according to Merrien et al., 1986), almost all of which is absorbed prior to the flowering stage. The salient feature associated with this element, however, is that most of the element absorbed is not actually taken up (only 20-25% is found in achenes). Depending on availability of the element in soil, fertilization can be carried out by applying roughly 100-150 kg/ha of potassium oxide (unless a situation of particular deficit has already been determined).

It can certainly be recommended that the planned quantities of phosphorus and potassium should be completely distributed during seedbed preparation, since these elements have low mobility in soil. As far as phosphorus is concerned, however, it could however prove to be of interest to evaluate the possibility of carrying out localized distribution of potassium along the row, partly in order to limit costs, while at the same time providing a further initial impulse to rapid crop establishment.

WATER - PLANT RELATIONS

WATER REQUIREMENTS

Under a regime of maximum evapotranspiration, present varieties of sunflower generally present a water requirement for the whole cycle amounting to 650 mm, with average daily consumption of 6mm. Peaks of over 10mm can however also be observed at times (Merrien, 1986). In other environments, on the other hand, average daily consumption of 5-7 mm. has been recorded (Robinson, 1978). At the outset of the cycle, daily evapotranspiration is low, even when grown as an intercalary crop with limited water supplement, so that no particular problems arise. But evapotranspiration increases with increasing leaf area, reaching maximum values in the period ranging from beginning of flowering to physiological maturation of achenes. This is the period in which maximum consumption occurs (Marty et al., 1972; Gimenez et al., 1975; Puech and Hernandez, 1973), and indeed during this stretch of time the ETM may exceed the ETP. As a result, throughout a considerable portion of the cycle the ratio ETM/ETP is greater than 1 (Merrien,1986), showing values that may even exceed 1.3 or 1.4 in high water requirement environments (Marty et al., 1972; Puech and Hernandez, 1973).

If water deficiency occurs at the moment when the flower bud appears, then growth of the leaf apparatus is slowed down (Muriel and Downes, 1874), while deficiency manifested during physiological maturation causes reduction in achene yield and achene oil percentage (Benvenuti et al., 1978; Blanchet and Merrien, 1982). Robertlin (1967) reported that the most critical period is the flowering stage. Water stress during this stage is known to cause lower production (Pirjol-Savulescu, 1974), while irrigation carried out during this same period leads to greater water efficiency (Marty et al., 1972; Unber, 1982). The general observation is that water stress reduces achene and oil yield, while protein percentage, which also depends on soil properties and crop management techniques, may in fact increase at times (Lencerot et al., 1973; Decau et al., 1974). By virtue of the considerable development of the sunflower root system, with its ability to penetrate deeply (Blanchet et al., 1980; Maertens and Bosc, 1981), sunflower presents excellent capacity to extract water from soil, even when the latter's water capacity is extremely low (Berengena and Henderson, 1980). Root resistance to water transfer has also been studied (Morizet et al., 1983), showing that resistance is markedly lower in sunflower compared to maize. Stoma resistance to water vapor diffusion is rather weak, under good water conditions: it has been shown to be 2-3 times lower compared to that observed in maize or sorghum. Moreover, under elevated lighting levels (1000 W/m^2), increase in stoma aperture lowers stoma resistance even further (Merrien, 1986). Range of values for leaf potential, within which stoma resistance varies progressively, present considerable variability in sunflower. The literature shows threshold values of minus 12 bar, minus 15 - minus 20 bar (Merrien, 1981 b), or varying from minus 18 to minus 11 bar, according to whether potassium in the soil solution is present in ideal quantity or not (Morizet and Martel, 1983).

Sunflower water efficiency (which is defined by the ratio between total dry matter production and quantity of water consumed) is rather low, when measured under non-limiting water conditions. It has been shown that this crop is less efficient than others in utilization of this element (Shantz and Piemeisel, 1927; Vranceanu, 1974; Benvenuti et al:, 1978). This is to be attributed to its low resistance to water loss, which in turn is due both to its leaf structure (high number of stoma, all of substantial size) and also to its good total conductivity (Blanchet and Gelfi, 1978; Blanchet et al., 1980). Both these characteristics lead to considerable increase in consumption under non-limiting water supply (Robelin, 1975).

Low water efficiency can be explained by investigating the ratio photosynthesis/transpiration. Up to a temperature of 25°C similar evolution of both activities is observed, leading to constant efficiency. But above 27°C photosynthetic activity begins to decline while transpiration continues to increase, leading to lower efficiency in water utilization.

When water availability is limited, efficient utilization of this resource plays a prominent role and this is of importance if sunflower is to be a second crop. For water deficiency does not have a negative effect on photosynthesis, but there are other processes such as leaf variation compared to transpiration. Under moderate water stress, photosynthetic activity suffers less compared to transpiration because stoma closure has a greater effect on water exchange than on carbon dioxide movement.

Assimilation loss observed under limited water supply is generally due to overall reduction in the leaf apparatus rather than to decrease in assimilation activity of each individual leaf (Rawson et al., 1980; Merrien et al., 1981 a; Turner and Rawson, 1982).

Given that photosynthesis is less sensitive to water deficiency compared to the sensitivity observed for transpiration, it follows that in conditions of water deficiency, the ratio photosynthesis/transpiration, which indicates plant efficiency, rises from 20 to 50%. This derives from the fact that when the ratio ETR/ETM decreases, transpiration also decreases (-60%), whereas efficiency of photosynthesis declines only by 10-30% (Merrien, 1986).

IRRIGATION

Sunflower is known to be able to generate a reasonable amount of production even in conditions of water stress. The reason lies in that compared to other annual species (Maize, soya, sugar beet) sunflower presents a decidedly favorable ratio between evapotranspiration deficit and decrease in yield (Morizet et al., 1984; Morizet and Merrien, 1990). It is also known, on the other hand, that under non-limiting water conditions sunflower presents elevated transpiration levels accompanied by low water efficiency (Merrien and Greco, 1984; Rachidi, 1991; Rizzo et al., 1990).

The above-described constrasting plant water requirements explain why sunflower shows very little response to irrigation, especially if compared to crops such as maize and soya. According to Merrien and Grandin (1990), maximum crop yield can in fact already be attained if 70% of plant water requirements are met during the course of the entire cycle. Excessive water administration, on the other hand, may lead to notable drop in yield (Vannozzi et al., 1988).

Over the last few years research has pointed to the possibility of applying limited irrigation to sunflower without seriously affecting quantitative-qualitative yield. By exploiting sunflower capacity to withstand even intense water stress, high water supply can be confined to the stages most critical for production formation, which coincide in particular with the period between appearance of the flower bud and seed filling. Irrigation carried out exclusively during these phenostages proves to be particularly effective (Fig. N° 4), giving rise to production similar to or only slightly lower than production obtainable when irrigation is applied throughout the cycle (Losavio et al., 1983; Ferri and Losavio, 1988; Quaglietta Chiarandà et al., 1991).

It should be noted, in this connection, that yield components (calathide diameter, % sterile achenes, 1000 achenes weight) are only very slightly affected by irrigation applied before flowering. When two waterings are administered during the reproductive stage, oil yield presents no significant differences (for a satisfactory oil yield, however, the crop must be assisted during the final part of the cycle) (Quaglietta Chiarandà et al., 1991).

Spring-sown sunflower is more successful in exploiting ground water reserves built up during the winter. In this case, therefore, irrigation assistance can generally be considered unnecessary during the vegetative stage. Indeed, irrigation at the vegetative stage could lead to an over-exuberant leaf apparatus and hence to wasteful consumption.

Merrien and Grandin (1990) claim that a leaf index of 3 at the flowering stage can be considered sufficient to guarantee maximum production It follows that irrigation at initial stages of the cycle is justified only if the crop presents stunted development. In particular, these authors emphasize that irrigation is advisable only if the LAI is below 1.5 - 1.7 at the 2 cm flower bud stage.

WEED CONTROL TECHNIQUES

In order to achieve effective weed control while also safeguarding the environment and crop economy, best results can be achieved when use of chemical herbicides is accompanied by appropriate crop management techniques and a rational program of Integrated Weed Control (Caporali et al., 1987; Catizone, 1979; McWorther et al., 1982; Miele, 1987/a; Walker et al., 1982; Worsham et al., 1985).

Main agronomic techniques to be adopted are:

- crop rotation,
- crop management policy.

These direct and indirect techniques will be aided by the crop's own natural defenses.

According to the principles laid down by the most up-to-date crop management techniques, applicability and effectiveness of the above agronomic techniques must first be evaluated, before proceeding to adoption of chemical herbicides either as a preventive measure (prior to sowing or during the pre-emergence stage) or as a direct means to combat weeds (during the post-emergence stage).

The most effective agronomic technique for weed control is undoubtedly that of rotation. Rational application of the succession of crops - wherever it can be carried out - can definitely bring about a marked reduction in weed aggressiveness, even if total elimination may not be achievable. For crop succession generates different conditions of antagonism towards spontaneous flora linked to the different cycles (summer or winter, wet or dry season), to the different plant habitus, different investment, different crop management techniques (fertilization, irrigation, etc.).

It is generally accepted that in areas where sunflower cultivation is intense, the interval between two sunflower crops should range from 2 to 5 years.

The longer interval not only has the effect of guarding against undesired colonizations, but also renders certain diseases less virulent, and may indeed even lead to a reduction in presence of certain vegetal parasites, in particular when winter cereals are introduced into the succession.

The specific topic to be dealt with at this point, however, concerns the degress of competition exercised by sunflower towards various weed species.

Sunflower intereferes with weed growth through allelopathy and competition. Allelopathy arises through the action of a chemical agent added to the environment in the form of an allelopathic agent, while competition is linked to essential factors of vegetal growth (Rice, 1974).

Wilson et al. (1968) discovered typical traits of allelopathy in several wild sunflower strains. Subsequent research by Leather (1983), aiming to ascertain whether current hybrids and varieties of sunflower have preserved these traits, showed that in sunflower, unlike other cultivated species, many selected lines (above all Ha 201; Ha 8944 and Romsun HS-52) maintain and at times even intensify the natural allelopathic potential of the wild species. This phenomenon occurs even if its effects are not readily observed in the open field because of the tendency of allelochemicals (among which various phenolic acids) to be lixiviated. Several studies also indicate that within certain limits production of these substances is linked to environmental conditions in which the composita is grown. UV radiation stimulates sunflower synthesis of scopoline and chlorogenic acids. The latter are also produced in greater quantity under conditions of water stress and nitrogen deficit (Putnam, 1985).

The above-described situation opens up new avenues of research in the sphere of genetics and biotechnology, with the aim of creating new genotypes capable of interfering more effectively in weed development, thereby reducing need for application of herbicides.

It should be noted, however, that sunflower also competes with weeds for growth factors. This natural aptitude should be enhanced by appropriate agronomic techniques so that plantlet vigor can be boosted from the start, enabling early soil shading to be achieved.

Careful quality seed selection is therefore necessary. Seeds characterized by high germination energy and low heat requirement (Gimeno-Ramirez, 1975), together with optimum seedbed preparation and plant disease control, represent the essential starting point of any integrated weed control system.

Sunflower is negatively influenced by weeds even at the early stages of the biological cycle, when low temperatures, which are a frequent occurrence during the spring period, lead to slow rate of growth (Johnson, 1971; Nalewaja et al., 1972; Covarelli and Tei, 1983). It is therefore vital to ensure weed control in the early period of crop growth. Lack of adequate weed control in the first 20-30 days of the plant vegetative cycle may lead to considerable decrease in production (Nalewaja et al., 1972; Covarelli et al., 1983). Furthermore, in Mediterranean-type environments weed elimination is essential to guarantee that the crop is allowed maximum availability of limited soil water reserves.

Sowing dates have notable effect on the type of weed appearing in the crop (as well as affecting production parameters, as is to be expected). Greater percentage of weeds in early-sown crops may also be dependent on increased rainfall during initial crop stages (Vannozzi et al., 1987). When late sowing dates are chosen, on the other hand, reduction in the interval between sowing and emergence, and between emergence and flowering leads to an increased GDD/day ratio (Robinson, 1971). This too may be useful in shortening the period during which sunflower is most susceptible to weed competition.

The type of weeds observed vary with varying sowing dates. In Central Italy, for instance, if crops are sown at the end of the cold season, weeds present in the crop tend to belong to the orders Centauretalia Cyani and Chenopodietalia Albi. This same association of flora is predominant in late sowings (Covarelli, 1986; Vannozzi et al., 1990). When ultra-late sowing is chosen for sunflower, (i.e. as a second crop), weeds are similar to those observed in maize and belong to the association Panico-Setarion (Covarelli, 1981; Tei, 1986). The following weeds are known to be particularly damaging in Central Italy: Sinapus Arvensis, Chenopodium Album and Amni Majus (Covarelli et al., 1984; Covarelli, 1986).

Plant density appears to have no effect on extent of weed presence (Vannozzi et al., 1987).

Equally important is efficient crop fertilization. It has been observed that frequency of weeds increases when nitrogen fertilization is increased to 200 kg/ha (Vannozzi et al., 1987).

By contrast, Miele (1988) studied band fertilization carried out by newly devised machines, built to perform the special type of minimum tillage known as strip-tillage (**) which is suitable for crops with wide inter-row spacings. In Miele's four-year trial considerable reduction was achieved in weed growth along untilled and thus unfertilized strips of ground, which had however been treated with herbicide, compared to the control crop sown according to the traditional manner.

One possible explanation of the phenomenon may lie in the observation put forward by Miller et al., (1979), claiming that full utilization of several growth factors present in soil can be obtained only provided that these factors come to be in the close vicinity of root systems within a very few days. For phosphorus, nitrogen and water the minimum distances beyond which there is no competition between weed and crop roots are 0.2cm, 2.0cm and 8.0 cm respectively (though for soluble forms of N, the measure is defined by distance at which water can be drawn).

Thus the diminished weed access to nutrients, together with greater and earlier nutrient utilization by crops, could be responsible for the observed phenomenon. But it should not be forgotten that nany weeds appear to be negatively influenced by low nutrient levels, above all by

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** This technique, carried out either on previously undisturbed or on ploughed ground, requires a double layer of tillage, namely estirpating down to a depth of 30 cm. and then shallow rotary hoeing, over a band representing about one-third of the surface. This area, 25-30 cm. wide and the same measurement deep, forms the strip in the center of which the crop is to be sown. At the same time as tilling, localized fertilization is applied uniformly throughout the band, allowing nutrient enrichment of the volume of soil where greatest expansion of root systems will preferentially take place. The aim is to increase likelihood of most of the fertilizer being intercepted and absorbed by the crop.

low phosphorus. As early as 1955 Vengris et al. showed that poor availability of the element in assimilatable form is responsible for a drop in frequency of Amaranthus retroflexus and Chenopodium album. Subsequently Smith et al. (1966), in research on rice, showed that control of phosphate fertilization (as regards dates and methods of application to crops) allows better control of Echinochloa crus-galli.

COMPLEMENTARY CROP MANAGEMENT TECHNIQUES

Sunflower is usually sown on ploughed land, and it is only recently that alternative techniques based on reduced tillage have been proposed in Italy in order to cut costs *(Miele, 1987). To date, specific data on the effect of this* variable on weed development in this oil-bearing crop are not available.

In general, it has been observed that seed survival is greater in undisturbed ground (Roberts et al., 1972), while research on other crops where minimum tillage systems are more widespread (maize, soya) has shown that dicotyledons are relatively constant, while incidence of gramineous grasses and perennial weeds tends to increase (Wruke et al., 1985). If the same proves to be true for sunflower, then the situation is likely to be similar to that observed in other crops, where appropriate rotation allows choice of suitable herbicides to control the various types of weeds.

Post-emergence intervention frequently involves mechanical cultivating and earthing up in order to achieve better control of any weeds that may have escaped herbicide treatment, to reduce evapotranspiration and improve plant anchorage.

Recently doubt has been cast on the validity of mechanical intervention aimed at completing prior chemical *herbicide treatment (Pouzet et al., 1983). Research in Italy* has however produced diverging results depending on the environment taken into consideration: at times favorable effects on yield have been recorded (Saleram 1986), while in other trials this was not the case (Covarelli et al., 1984/b). So far there are no definitive conclusions regarding agronomic and economic evaluation criteria to assess different proposals that have been or could be proposed (herbicides along during pre-emergence, double intervention, herbicides in pre-emergence + 1 or 2 interventions with the mechanical cultivator, completed or not completed by earthing up).

Mechanical cultivating is generally carried out by means of spring-tined or rotary cultivators. The latter, characterized by relatively high speed of forward movement (up to 16 km/h), achieve good control of between-row weeds, allowing effective break-up of surface crust at the same time. Spring-tined cultivators, on the other hand, which operate at speeds of 4-8 km/h, achieve better weed control, easily uprooting weeds provided that these are relatively undeveloped, but in comparison to rotary cultivators they are less effective in breaking up surface crust (Robinson, 1978).

Together with mechanical cultivating, earthing up may or may not take place at the same time, with the intent of eliminating weeds developing along the rows.

USE OF CHEMICAL HERBICIDES

Sunflower may be subjected to chemical herbicide treatment prior to sowing, even if sowing takes place at an early date, during pre-emergence or post-emergence.

Pre-sowing herbicide application is carried out in combination with winter preparation of the seedbed, allowing early sowing of the crop on soil structured by atmospheric agents. Postponement of sowing due to waterlogged soil, a frequent condition in spring which delays seedbed preparation, is thus unnecessary (Covarelli, 1986). This form of management, often proposed in various areas of Central Italy, does however present a number of problems of an ecological nature, since it is generally carried out on clayey soils, frequently on slopes and therefore subject to laminar erosion phenomena. If one considers that that early herbicide application often makes use of products such as metobromuron and linuron, which are applied to the surface without being dug in (Monotti, 1980), then it becomes clear that routine problems of erosion are compounded by greater risk of pollution of bodies of water due to water run-off, which carries along soil particles that flow into mass transport.

In environments where these problems are less evident, experiments have shown that administration of metobromuron (1500 g/ha active principle) or linuron (916 h/ha active ingredient) 30-40 days prior to sowing ensures low presence of weeds, at least until the crop provides total ground cover (end of May-beginning of June). Should weeds nevertheless come up, the seedbed can be cleared by light harrowing, or else a withering agent can be used (Covarelli), preferably in a reduced dose, transported in water with roughly 50 kg/ha solution of ammonium urea-nitrate in order to enhance its action (Miele, 1981).

If intervention prior to sowing is restricted to use of trifluralin (678-916 g/ha active ingredient), whose limited action spectrum means that treatment will subsequently be required during pre-emergence for control of compositae and cruciferae, weed control in sunflower is predominantly achieved by recourse to active ingredients and blends to be applied in pre-emergence.

The most widespread blends are the following (Tei, 1986; Vànnozzi et al.,1986; Laureti, 1986; Tei, 1986; Covarelli, 1988; Salera and Baldini, 1988; Pirani, 1989; Tei et al., 1991; Salera, 1991):

metobromuron + prometryn (500 + 100 g/ha a.i.);
linuron + trifluralin (470 + 940 g/ha a.i.):
metobromuron + metazachlor (750 + 100 g/ha a.i.);
linuron + alachlor (500 + 1728 g/ha a.i,);
metobromuron + metolachlor (500 + 1027 g/ha a.i.);
linuron + pendimethalin (540 + 960 g/ha a.i.);
fluorchloridone + metolachlor (500 + 960 g/ha a.i.);
oxadiazon (750 g/ha a.i.);
oxifluorphen (236 g/ha a.i.);
oxifluorphen + alachlor (236 + 1729 g/ha a.i.).

Turning now to post-emergence treatments, the most frequently used chemicals are based on the following a.i.:

pendimethalin (1205 g/ha a.i.);
imazametabenz (300-400 g/ha a.i.);

Different chemicals are however generally used to control post-emergence graminicides. The following in particular are frequently used on compositae:

dichlofop-methyl (711 g/ha a.i.);
fluazifop-butyl + nonylphenol (625 + 90 g/ha a.i,);
setoxydim + oil (400 + 1500 g/ha a.i.);
quizalofop-ethyl + oil (102 + 1600 g/ha a.i.);
alloxyfop-ethoxyethyl (125-250 g/ha a.i.).

CONCLUDING OBSERVATIONS

Modern crop management systems have provided a valid contribution to diffusion of sunflower cultivation in different world agro-climatic environments, but state-of-the art research-based agrotechnology has not yet fully illuminated all aspects of the agrarian ecosystem, and there is still no complete understanding of the manner in which a crop adapts to this ecosystem. Better understanding of interaction between various environmental factors should aid further increase in yield.

Substantial production increase is to be expected from creation of new genotypes, for sunflower is a relatively young crop in terms of genetic improvement. Knowledge of sunflower physiology is still limited, making definition of the ideotype a difficult task. For instance, the limited conversion of flowers into seeds represents one aspect requiring greater physiological knowledge before genetic improvement can be attempted. Simulation models will bring about better crop field conditions, optimization of crop management practices (irrigation, nitrogen fertilization, weed control, crop defense). Researchers also look to simulation as a means to acquire greater understanding of aspects of plant physiology, such as the way changes in plant canopy structure influence light penetration and photosynthesis efficiency. Moreoever, the quest for identification of the physiological ideotype can benefit greatly from use of simulation models.

Introduction of sunflower into new areas of cultivation, such as tropical and sub-tropical environments, must be accompanied by genetic improvement programs with the goal of increasing crop adaptability to the high temperatures and short photoperiod characteristic of such environments. In these areas, furthermore, high temperatures are accompanied by a highly variable rainy season, with rainfall often restricted to areas where in any case soil has only limited water retention capacity and is sometimes saline. It is hoped that knowledge of physiological mechanisms linked to drought resistance will lead to creation of hybrids fully adapted to this new environment.

In temperate and Mediterranean-type environments the major limit to further increase in production is represented by water scarcity during the summer period, when evaporation demand rises sharply. Here too, creation of drought-resistent hybrids with high water efficiency and high harvest index should provide the best solution.

In northern Europe, resistance to low temperatures together with introduction of genes for disease resistance appears to be one of the factors limiting the spread of sunflower in this area. Creation of low- temperature-resistant photoindifferent types could allow sowing dates to be brought forward to the winter period, with better use of soil moisture and rainfall, as suggested by results obtained in Spain.

It should in any case be kept in mind that introduction of new disease-resistant genes represents a priority factor for all areas of sunflower cultivation.

Better understanding of temperature toleration and drought resistance mechanisms will be obtained through identification of plant physiological, biochemical and molecular indicators. Utilization of such indicators for genetic improvement and crop management will however require interdisciplinary research, encouraging joint study by physiologists, agronomists, biochemists, molecular geneticists and breeders.

The above observations have sketched out the crop management techniques most suited to dealing with the genetic material available to date, and most appropriate for study of present-day diffusion of sunflower in the various pedoclimatic areas. Naturally, however, should new hybrids become available, characterized by greater adaptability and disease resistance, lower water requirements and different quality of product, agronomic techniques will need to be reconsidered and adjusted to the new situation.

Fig. 1 - World cultivated area and yield during last ten years (Source: F.A.O.).

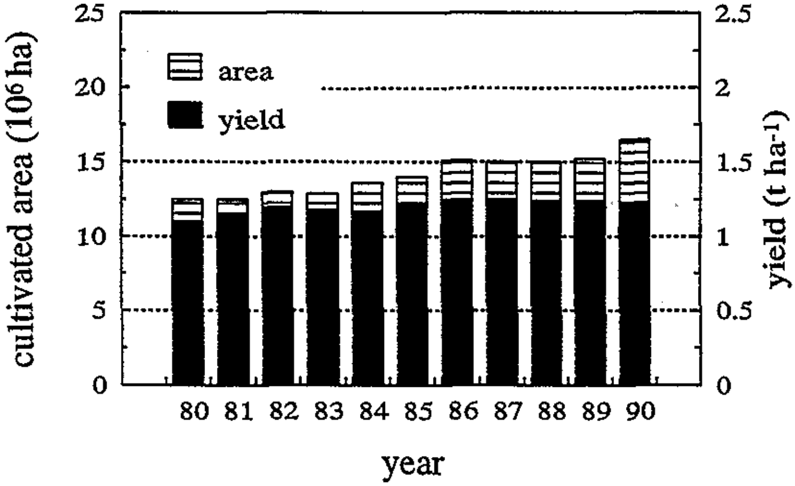


Fig.2 - Yield index (100=cv *Mirasol*) for new cv certificated in France during last years. (Source C.E.T.I.O.M.).

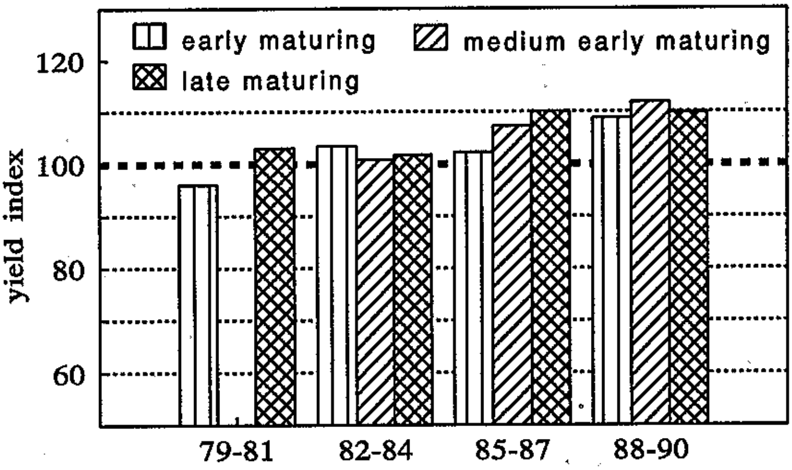


Fig. 3 - Plant density effect on grain yields (cv. *Stromboli*) (cv. *Stromboli*) from different trials in Italy.

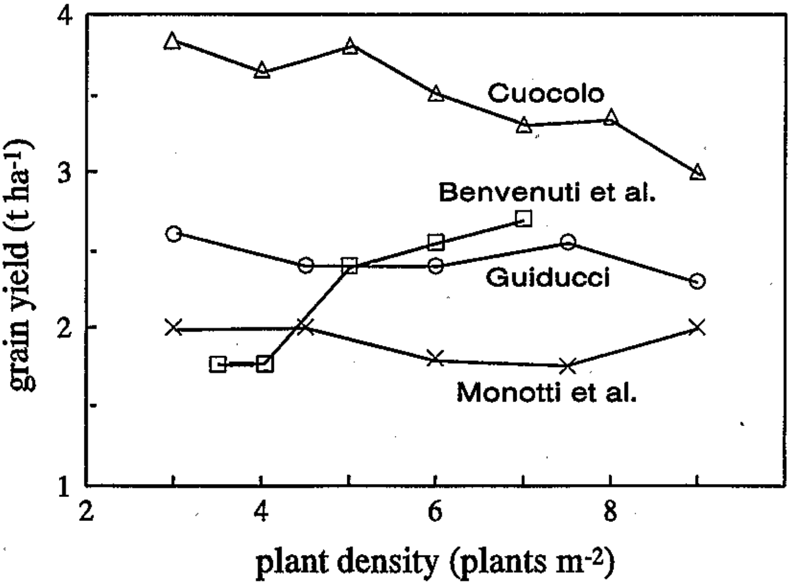


Fig. 4 - Pisa. Plant density effect on the yield.

Ten years average yields (1980-1990) with medium-tall and dwarf hybrids

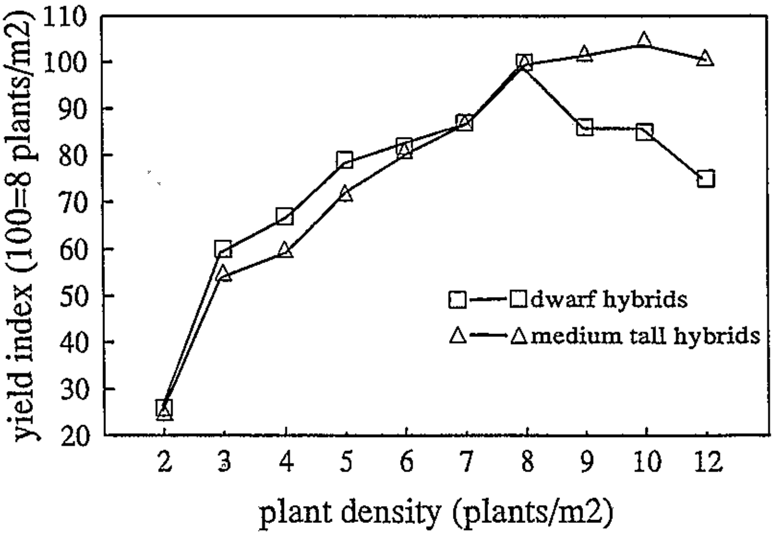


Fig. 5 - Pisa. Inter-row spacing effect with different hybrids. Data are ten year average yields (1980-1990)

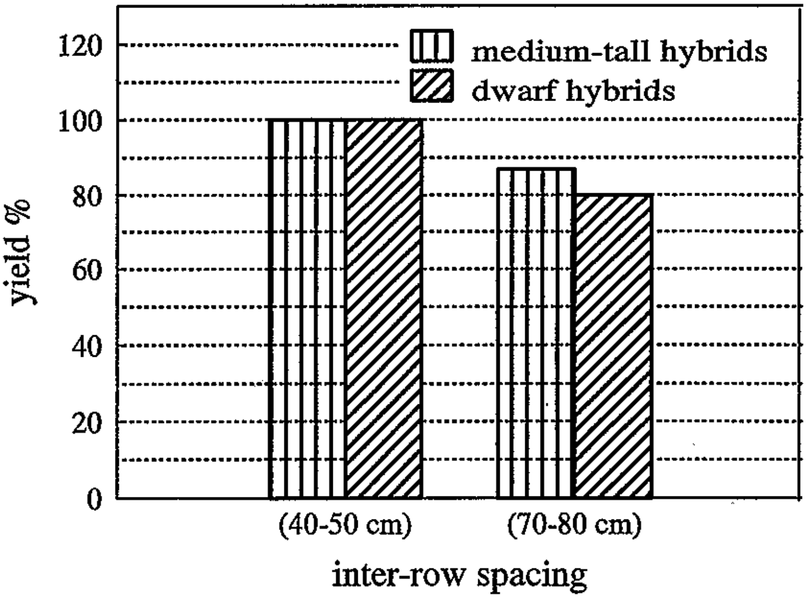


Fig.6 -Pisa.Plant density effect on the oil cake quality.

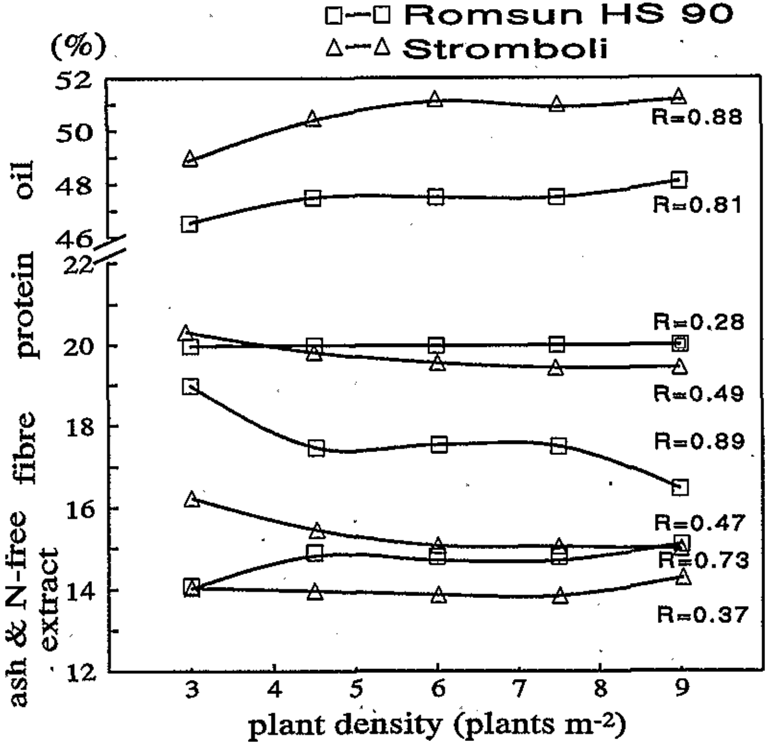
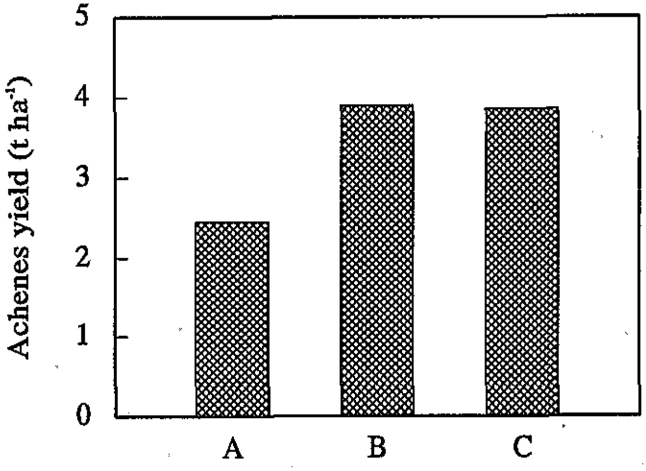


Fig. 7 - Pisa. Achenes yield with different water regimes.



(A=not irrigated; B=irrigated during reproductive phase; C=irrigated at 90% of ETM)

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