A STUDY OF THE EFFECTS OF ROW SPACING AND SOWING RATE ON GROWTH, SEED YIELD AND SEED QUALITY OF SAFFLOWER. (*Carthamus tinctorius* L)

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KHALIP ABDUL RAFFAR

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SUMMARY

In this study on safflower production, the experimental data showed that the square planting treatment produced the highest seed yield per unit area. As row width increased, a steady decline in seed yield per unit area resulted. However, by increasing the sowing rate eight fold, the seed yield was more than doubled (2699 to 6200 Kg/Ha).

The significantly high seed yield per unit area obtained from the square planting treatment and the highest sowing rate treatment was largely due to the total number of seed heads produced. This was confirmed by the high and positive correlation between seed yield and the number of plants and number of seed heads per unit area. However, on a per plant basis, seed yield appeared to depend on the number of heads per plant, head weight, number of seeds per head and seed weight.

From data obtained in this study, both row spacing and sowing rate affected the growth and development of safflower. At the same sowing rate, it appeared that narrow row spacing and square planting resulted in bigger plants with a greater number of leaves and branches and also earlier flowering. Wide row spacing (72 cm) showed only one positive trend in plant character, viz. an increase in height.

The main effect of increasing the sowing rate was the reduction in plant size, its associated features (i.e. fewer branches and leaves), and the delay in flowering.

Growth analysis revealed that RGR, NAR and LAR showed

a rapid initial increase during the first 7 weeks before starting to decline with time. This trend in safflower growth curves may be attributed to its peculiar growth pattern which includes the rosette stage, after emergence. In this study, the seedlings remained in this rosette stage for approximately 5 to 6 weeks with little evidence of growth activity. The CGR of safflower was in fact found to be similar to that of soybean but greatly accelerated after the rosette stage. Harvest index (HI) values were high and corresponded to the high seed yield obtained in this study.

Evidence from growth components i.e. RGR, NAR, LAI and LAR showed little support in their relationship with the high seed yield as far as row spacing treatments were concerned. However, in sowing rate treatments, the relationship between LAI and high seed yield was evident but other growth components showed no such relationship.

Neither plant spacing nor sowing rate had any significant effect on seed moisture and seed viability. Seed oil content, which ranged from 26 - 28%, was also not significantly affected by the different treatments.

From the evidence of this study, it appeared that plant competition had been the major factor affecting safflower growth and development. It is concluded therefore, that this agronomic aspect of safflower needs further research under controlled environment conditions.

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INTRODUCTION

Major interest in the potential of oil seed crop in New Zealand agriculture has been shown over the past few years. Through extensive research, soybean has been successfully established as a crop in local agriculture. This is evident by the substantial increase in soybean acreage (2000 - 3000) in the Gisborne area this year. In the South Island, oil seed crop such as sunflower has also been grown successfully.

The main interest in oilseed crop production is the oil and its composition. Vegetable oils which contain high level of polyunsaturated fatty acids are highly sought after because of their low cholesterol property. In the past, this type of oil has been used mainly for making low cholesterol content margarine and cooking. However, the recent interest in easy-spread butter and the discovery by research scientists of the C.S.I.R.O. in Australia that feeding stock with vegetable oils containing poly-unsaturated fatty acids reduces cholesterol levels in both meat and milk have increased interest in oilseed crop in this country.

Safflower is one of the oilseed crops known to produce oil containing very high polyunsaturated fatty acids (73-80%). However, lack of agronomic information in New Zealand may well hamper the possible large scale production of this crop. Thus, the present study is an attempt to gather some information regarding the growth of safflower under local conditions. Planting pattern and sowing rate are two of the major considerations in its successful development and an early understanding of these agronomic factors is regarded as important for the rapid expansion of a potential oilseed crop industry in New Zealand.

CHAPTER ONE

1.1 SAFFLOWER - DESCRIPTIVE

1.11 HISTORY

Safflower (Carthamus tinctorius L), one of the world's oldest crop, is thought to have originated either from Carthamus lanatus L (saffron thistle) or Carthamus oxyacantha Bieb (wild safflower) (Knowles 1958), in two primary centres of origin viz. the mountainous regions of Abyssinia and Afghanistan (Knowles 1955 and 1958; Weiss 1971). For centuries its culture was confined to regions of India and other areas of Asia, Africa and Europe, where the flowers were used a source of dye for clothing and food (Cobley 1957; Knowles 1955 and 1958; Knowles and Miller 1965; Weiss 1971). In recent times safflower has been introduced to the United States and South America (Beech 1969; Knowles 1955), South Africa and Australia (Anon. 1963; Horowitz and Kleinig 1958; Knowles 1955 and Weiss 1971).

1.12 BOTANY

Several investigators have recorded the botanical characteristics of safflower (Anon. 1961; Beech 1969; Classen 1949 and 1950; Cobley 1957; Knowles 1955 and 1958; Know les and Miller 1965; McGregor and Hay 1952; and Weiss 1971). Taxonomically safflower belongs to the compositae subfamily Cynareae. The plant is a much branched, herbaceous, thistle-like annual varying in height from 30 - 150 cm. It has a deep tap root with numerous thin laterals and a strong stem w hich is stiff, solid, circular in section, thick at the base and tapering with height. All branches are terminated by individual flowering head consisting of 20 - 150 tubular hermaphrodite florets and the extent of branching varies with environment, variety and plant spacing. The leaves are simple, usually dark green and short spines may or may not be present depending on the variety. The flower heads or capitulum are protected by several series of involucral bracts. The inner involucral bracts are imbricated in several layers around the head and completely enclose the unopened florets.

Flowering begins in the head that terminates the main axis (primary head) of the plant and proceeds basipetally with the upper branches flowering first and the lower branches last. The flowers of an individual head open over a period of 3 to 6 days. Those at the margin of the head open first and flowering proceeds centripetally. Flower colour varies with varieties from red through orange and yellow to white. Each floret may produce one seed, an achene, with a white hull (pericarp) and the pappus normally absent. New varieties have grayish, brown or striped seed. The seed is oleaginous and exalbuminous.

1.13 VARIETIES

Safflower varieties differ in flower colour, degree of spininess, diameter of seed heads, oil content, resistence to disease, and ease of harvest.

Most widely grown varieties were known as N-10 and Pacific 1 and other commercially important varieties are US-10 and GILA (Anon. 1961; Knowles and Miller 1965). Recent work on safflower selection and hybridization has produce varieties with higher oil content (Ashri and Knowles

1960; Ebert and Knowles 1966 and 1968; Urie and Zimmer 1970a and 1970b). These new varieties include the thin-hull and strip-seed character (Ebert and Knowles 1966 and 1968; Knowles and Miller 1965) and the reduced -hull seed character (Urie and Zimmer 1970b).

The new variety is referred to as striped because the hull of the seed has alternating white and brown stripes. The other type is termed thin-hull because it has paper thin hulls, grayish or brownish in colour (Knowles and Miller 1965). The thin-hull type cannot be used directly in commercial production because of the pleiotrophic manifestations of the th gene giving weak stems and structures and male sterility (Ebert and Knowles 1966).

The latest release is the reduced-hull character resulting from a reduction of outer sclerenchyma layers of pericarp. Studies have shown that reduced-hull lines significantly outyield US-10, a standard check variety (Urie and Zimmer 1970a). Hull reduction is of practical importance in view of the negative correlation between oil content and hull percentage (Beech 1969; Classen et al 1950; Pawlowski 1961; Yermanos and Francois 1963; Yermanos et al 1967). According to Knowles and Miller (1965), with less hull, the whole seed oil content is above 40% and the protein content increases from 12 - 15% up to as high as 21%.

Another variety of safflower has been discovered which gives a completely different type of oil from the normal type of safflower. This variety, UC-1, has a high percentage of oleic and low linoleic acid, the reverse of the normal type (Knowles 1965). The original line was found in Australia (Horowitz and Winter 1957). The change in the proportion of oleic and linoleic acid makes the oil from this variety chemically similar to olive oil. The variety UC-1 has an average oil content of 36% and iodine value of 90.

The variability in the composition of the oil is the most interesting aspect for future beeding work. Knowles and Hill (1964) in their investigation found that selections from an introduction from the Azerbaijan area of Iran have an oil with an iodine value ranging from 109 to 123, depending on environment. Apparently one allele is responsible for the fatty acid composition. This compares with the 'normal' iodine value of around 140. The oil composition also varies in having a linoleic acid content averaging 48% and oleic acid content of some 43%.

1.14 Climate

The cultivated safflower shows a fairly wide adaptability within certain geographical limits (Weiss 1971), but does not favour extremes either of heat or cold (Beech 1960 and 1969; Beech and Norman 1963; Phillis 1961 and Knowles 1958). Large scale safflower production is usually confined to areas below 900 metres because the low temperatures in the higher altitudes limits growth and restricts seed yield. Weiss (1971) reported that in the United States and Russia, safflower is grown commercially between 30° and 45°N and in Australia between 15° and 35°S, usually under irrigation, or with supplementary water available should the rainfall be insufficient.

1.141 Temperature

Frost-resistance depends mainly on variety and the stage of development of the safflower plant (Beech 1969; Classen and Hoffman 1950; Knowles 1955 and 1958; Knowles and Miller 1965; and Weiss 1971). In the United States, at seedling stage, most safflower varieties will tolerate temperatures down to -7^{o}C (Classen and Hoffman 1950). At elongation stage, safflower plants appear to be more susceptible to frost injury. Klarges (1954) observed that young plants had a varying degree of frost damage at a temperature of -2.2^{o}C. In Canada, safflower was reported to be uninjured by frost which damaged maize (McGregor and Hay 1952). At flowering and seed-maturation stage, the crop must be frost-free because frost can reduce the quality and yield of seed (Classen and Hoffman 1950; Harbison 1968; Klarges 1954).

Seed germination takes place when soil temperatures are above 40^{o}F (Classen and Hoffman 1950; Dennis and Rubis 1966; Knowles 1955; and Weiss 1971), and the rate of germination increases as temperatures increase up to 60^{o}F (Classen and Hoffman 1950; Klarges 1954; Knowles 1955; and Weiss 1971). Warm temperature during early growth reduces the period spent in the rosette stage, and the transition can be rapid when there is no cool period after emergence.

High temperature at flowering appears to have a detrimental effect on safflower. According to Phillis (1961), high temperatures tend to reduce the success of floret fertilization and thus subsequently reduces the seed yield. Other investigators (Knowles 1955; Knowles and Miller 1960 and 1965) have indicated that safflower tends to give higher yields when daytime temperatures at flowering and seed development are moderate, in the range of 24 - 32^{o}C.

However, Cavin (1965) found that high temperatures up to 26.5°C during seed development did not affect seed oil content or the fatty acid composition of the oil.

1.142 Rainfall

Although safflower is considered to be drought-resistant (Beech 1969; Classen and Hoffman 1950; Knowles 1955 and 1958; Palti and Hizani 1953; and Weiss 1971), adequate soil moisture is essential to see the crop through to maturity (Knowles 1955; Knowles and Miller 1960 and 1965; and Weiss 1971). With adequate preplanting soil moisture and the absence of hot dry winds, 300 mm of rain prior to flowering will produce good yields (Weiss 1971). Safflower becomes more susceptible to hail damage during the stem-elongation stage (Beech 1969; Knowles 1955; and Weiss 1971), and heavy rain during flowering can seriously affect pollination (Beech 1969 and Knowles 1955). Rain after flowering may discolour the seed and adversely affect its development and oil content. Also prolonged rain and warm temperature after the crop is mature causes the seed to germinate in the head (Knowles 1955 and Weiss 1971).

At all stages of growth, excessive rainfall or humidity favours fungal diseases such as leaf spot, rust, root rot and head rot (Davis 1965; Dennis and Rubis 1966; Harbison 1968; Knowles 1955 and 1958; Knowles and Miller 1965).

Prolonged rain or waterlogging due to poor drainage is detrimental to safflower. Damage to the crop is accentuated with high temperature (Knowles 1955; and Weiss 1971).

1.143 Wind

The mature plant is extremely wind resistant, and even after seeds are mature there are few losses from lodging or shattering (Weiss 1971). Knowles and Miller (1965) reported that in California, winds of 24 km per hour caused no damage to the crop. However, etiolated plants due to very close spacing may be damaged by wind (Weiss 1971).

1.2 General Growth Pattern

The growth pattern of safflower has been recorded by a number of workers. Of these, studies by Stern and Beech (1965) in Australia, and Knowles and Miller (1965) in U.S.A., give a good account of the general growth and development of safflower. Germination and development of safflower is very slow at minimum temperatures. During cold weather, time taken for seedlings to emerge may be up to three weeks. Seedlings emerge rapidly (3-4 days after planting) when soil temperature rises. After emergence, the seedlings remain close to the ground (rosette stage) and produce numerous leaves. The plants stay at the rosette stage for about 5-6 weeks before the stem begins to elongate. Rapid elongation occurs between 48 - 55 days after planting, and after 76 days branching and flowering begin. Seed formation takes place between 104 and 11 days from sowing and the seed matures in about 25 days after flowering. Within a head, the flowering and maturing of individual florets and seed may range up to 7 days. On the average, a field is ready for harvesting about 35 to 40 days after flowering.

Various factors such as temperature, availability of soil moisture, variety, weeds and disease infestations can modify the general growth pattern of this crop. (Beech

1960, Beech and Norman 1966, Knowles 1955 and Knowles and Miller 1965 and Weiss 1971).

1.3 Growth Analysis

In this section, the procedure of growth analysis is reveiwed. Various investigators have been involved in growth analysis of a number of crops but to date complete growth analysis of safflower is not available.

Before proceeding, growth analysis parameters and components are defined.

W = mean total accumulated dry weights.

A = mean total leaf area per plant.

RHO = the number of plants per unit area.

Relative growth rate (RGR) - dry weight accumulated per unit of plant dry weight per unit of time.

Net assimilation rate (NAR) - dry weight accumulated per unit of leaf area per unit of time.

Leaf area ratio (LAR) - leaf area per unit of plant dry weight.

Leaf area index (LAI) - leaf area per unit of land area.

Leaf area duration (LAD) - leaf area intergrated over time.

Crop growth rate (CGR) - dry weight accumulated per unit of land area per unit of time.

Harvest index (HI) - economic yield divided by total plant dry weight x 100.

Growth analysis have been reviewed by Eagles 1971; Radford 1967; Wallace et al 1972 and Watson 1952. With growth analysis, mean total accumulated plant weights (W), mean leaf areas (A), and mean dry weight of the different plant organs including weights of economically important organ (economic yield) are obtained at the beginning and end of a time period of plant growth. These parameters are used to calculate the various components of growth analysis such as RGR, NAR, LAR, LAI, LAD, CGR and HI and other measures of capacity and efficiency of growth and yield. The LAR indicates the relative a mount of A supporting a unit of W i.e. the photosynthetic capacity per unit of respiring and growing tissue. The function of LAR is further indicated in that LAR and NAR are physiological components of RGR. (RGR = NAR x LAR).

Buttery (1969) illustrated the effects of planting density and fertilizer treatments on various growth components of soy bean. NAR decreased with increasing planting density and declined in all treatments throughout the growing season. RGR declined linearly with time and the lower values of RGR were clearly associated with higher densities. The application of fertilizer however tended to slow the decline in RGR. LAR declined with declining density in the early stages but toward the end of the growing season the situation was reversed. There was in increase in CGR for the first 60 - 70 days but it declined quite sharply after that period. Higher densities generally resulted in higher value of CGR. Under conditions of low illumination (i.e. high population density) high LAR value would be expected (Buttery 1969). Stern and Beech (1965) reported that the LAI of safflower rose rapidly to a peak of 4.5 at 62 days from planting and declined to almost nil by the final harvest.

During the peak growth, there were approximately 100 leaves per plant. They also found that the low HI values were possibly due to the direct effect of high temperature during flowering and ripening.

1.4 Growth and Development

In this section, the various factors affecting the crop establishment, vegetative and reproductive growth and development of safflower will be reviewed. Greater emphasis is placed on the following factors, i.e. population density, seeding rate, plant spacing and planting pattern since they are most relevant to the subject of this thesis. A brief account of the other factors is also included.

1.41 Factors Affecting Growth and Development

Safflower can be successfully grown on a wide range of soil types (Knowles 1955; Weiss 1971), but does very well on fertile, fairly deep and well drained soil of neutral reaction. (Classen and Hoffman 1950; Kapusta et al 1962; Knowles 1955; Peterson 1965; Shaw and Joppa 1963; and Weiss 1971). For good crop establishment, the seed bed should be well prepared with firm subsoil, a surface tilth free from large clods and moist at 1 in. below the soil surface (Anon 1961; and Weiss 1971).

About 300 mm of rain is essential for a good crop (Knowles 1955; and Weiss 1971). In irrigated crops, depending on variety and location, safflower requires about 2 - 3.5 feet of water. (Beech 1960; Knowles 1955; Knowles and Miller 1965; Luebs et al 1965; Stern 1965; and Weiss 1971).

Safflower responds to fertilizer application, N in particular, where adequate soil moisture is available. (Beech and Norman 1968; Jones and Tucker 1968; Knowles and Miller 1960 and 1965). The crop requirements depend on the soil fertility, the previous cropping history and the available moisture (Anon. 1963; Beech 1960; Dennis and Rubis 1966; and Weiss 1971).

The growth habit of safflower makes it extremely susceptible to weed competition in the early growth stages. (Knowles and Miller 1960 and 1965; Weiss 1971). Heavy infestations later in the growing season tend to interfere with mechanical harvesting (Knowles and Miller 1960 and 1965; and Weiss 1971). Both these factors tend to reduce safflower yields thus weed control is essential. Under dry land conditions weed control is achieved by harrowing, (Classen and Hoffman 1950; Klages 1954; Knowles 1955; Shaw and Joppa 1963; Tongren 1964; and Weiss 1971), and inter-row cultivation is practiced when the crop is grown in beds or under irrigation (Anon. 1961; Classen and Hoffman 1950; Knowles 1955; and Tongren 1964). Recently, selective herbicides have become available for use in safflower (Knowles and Miller 1960 and 1965; Tongren 1964; Van Rijn 1962 and Weiss 1971). Investigators have shown that pre-emergence herbicides such as EPTC, trifluvalin and diuron are superior to those of post-emergence which appear to depress seed yield and injure safflower (Knowles 1955; Tongren 1964; Van Rijn 1962; and Weiss 1971).

Extensive literature on diseases of safflower have been published by Klisiewicz (1962, 1963, 1965, 1966, 1967 and 1970), Thomas (1952, 1956, 1960 and 1963), Zimmer (1961, 1962, 1963, 1965, 1967 and 1968) and Zimmer and Urie (1967, 1967a, 1969, 1969a and 1970). The most common diseases are rust, root rot, leaf spot, bud rot and verticillium wilt (Anon. 1961; Ashri 1961; Dennis and Rubis 1966; Knowles and Miller 1960 and 1965; Thomas 1952; and Thomas et al 1963). The severity of these diseases depends on climatic conditions, cultural practices and variety (Anon. 1961; Dennis and Rubis 1966; Knowles 1955 and Weiss 1971). Recently, virus diseases associated with safflower have also been discovered. (Klissiewicz 1966 and Klissiewicz and Thomas 1970).

Although safflower can be attacked by many insect pests, only a few are of economic importance. (Knowles 1955 and Weiss 1971). The major pests are safflower fly (<u>Acanthiophilus helianthi</u>), cluster caterpillar (<u>Spodoptera litura</u>), thrips and larvae of <u>Heliothis</u> spp. (Anon. 1961; Beech 1964; Carlson 1964 and 1966; Knowles 1955 and 1958; Knowles and Miller 1960 and 1965; and Weiss 1971). During the early seedling stage, wireworms, aphids and thrips are the main ones to watch (Anon. 1961; Knowles 1955; and Knowles and Miller 1965).

Safflower is also susceptible to a number of root knot nematodes particularly at high soil temperature (Lear et al 1966 and Weiss 1971).

1.411 <u>Seeding Rates</u>

Plant population is one of the important factors in determining crop yields. With sunflower, plant spacing significantly affected seed yield, weight of seed per head, seed size and head and stem diameters (Massey 1971). With other oil seed crops such as soy bean, by increasing planting density, the plant weights, the weights and numbers of most plant parts were depressed (Buttery 1969 and 1970; Hanson and Hinson 1961 and 1962; Lehman a nd Lambert 1960; Shibles and Weber 1965). The effects of high density were more obvious with later samples, indicating that competitive stress increased with the growth of plants (Buttery 1969).

Methods of achieving the optimum plant population for safflower production have been studied by Beech (1960 and 1963); Beech and Norman (1965 and 1966) in Australia and in U.S.A., Hoag et al (1968); Peterson (1965); Weiss (1971) and Williams (1962). Seeding rate of safflower depends on several factors, namely method of production i.e. non-irrigated or irrigated; time of planting; row width and method of sowing and variety (Beech 1969; Classen and Hoffman 1950; Knowles 1955; Knowles and Miller 1965; McGregor and Hay 1952; and Weiss 1971). The major factor in determining plant populations under non-irrigated conditions is available moisture. In the U.S.A., for the same row spacing, the irrigated crop is generally sown with 25% more seed than the non-irrigated crop. In Queensland for non-irrigated crop, the sowing rates vary from 10 to 55 lb per acre and the row spacing from 7 to 21 inches. (Anon. 1963; and Harbison 1968). With similar growing conditions in U.S.A. seeding rates of 20 - 40 lb per acre are commonly used in close-drilled crops and 15 - 20 lb per acre for wide-spaced crops. In other countries such as India, Hungary and Israel, the sowing rates range from 40 - 80 lb per acre for close drilled crops (7 - 10 inches spaced rows) and 20 - 25 lb per acre for wide-spaced crop (Anon. 1961; Beech 1960; Classen and Hoffman 1950; Knowles and Miller 1960; and Shaw and Joppa 1963). The higher seeding rates provide good weed control, but lower rates may be necessary where there is a lack of moisture (Classen and Hoffman 1950 and Knowles 1955).

At Kimberly in Australia, maximum seed yield was obtained at a density of 247,000 plants per acre. Assuming that there is 100% emergence and based on 10,000 seeds per pound, a seeding rate of approximately 25 lb per acre would achieve this plant population. However, a population density of less than 120,000 plants an acre gave reduced yields at 3 foot row spacing (Stern and Beech 1965). Later, Beech and Norman (1966) reported that a drilled crop of 593,000 plants per acre yielded less than the optimum row-crop density of 114,000 plants to an acre. They concluded that under Kimberly conditions, the optimum population density for safflower is approximately ¼ million plants and ⅛ million plants per acre for drilled crop and row crop respectively.

1.412 The Effect of Population Density and Spacing on Growth and Development

Stern and Beech (1965) carried out a plant density trial with populations of 25, 50, 100, 520 and 1120 plants per square meter and showed that the first three levels of population were not significantly different in the number of plants at harvest. At the 520 and 1120 levels, numbers fell by over 40% in the first six weeks after emergence. The population gained equilibrium at about 100 days after emergence.

The main effect of increasing plant density was to reduce plant size. Plants too close together tended to have thinner tems or a more superficial root system, becoming susceptible to wind and storm damage (Weiss 1971).

The dry weight of tops per plant fell steadily with increasing density (Beech and Norman 1965 and 1966). Williams (1962) found that plants in wider plant spacings produced many more secondary and tertiary branches. In the 1-inch plant spacing, there were only a few secondary heads and frequently no tertiary flowers. In a row spacing study, Hoag et al (1968) observed that narrow row spacing (15 cm) resulted in advanced plant development compared to those in 53 - or 91 - cm spaced rows. However, plants in 91 -cm spaced rows were taller than plants in 15 or 53 cm spaced rows at the bud stage. At maturity, there was very little difference in plant height from all three row spacing treatments.

Plant density has a major effect on the size and number of leaves per plant. Beech and Stern (1965) illustrated the effect of five population densities (25, 50, 100, 520 and 1120 plants per square meter) on the number of leaves per plant. At the early stage, the effect of density on leaf numbers was already apparent, the highest plant population having half the leaves per plant of the lowest. The number of leaves rose quickly between five and ten weeks after sowing, reaching a maximum at thirteen weeks and then falling sharply. The degree and number of branches was directly related to the total number of leaves. Plants with the lowest total leaf number were those from the highest population, which also had the least branching.

Plants in narrow rows appear to bloom significantly earlier than those in wider spaced rows (Hoag et al 1968). Beech and Norman (1966) observed that with increasing plant density the span of time over which flowers bloomed decreased. Williams (1962) however, indicated that increasing plant spacing did not influence the mean date of flowering.

With respect to yield attributes, Beech and Norman (1966) found that number of heads, number of seeds and seed yield on per unit area basis increased up to 114,000 plants per acre and then fell sharply. But on per plant basis these attributes fell steadily with increasing density. Plants in wide-spaced rows produced more heads per plant, more seed per head and heavier seeds than plants in narrow rows (Hoag et al 1968). Similar results were obtained by Williams (1962) in his plant spacing study.

Evidence from various studies on the effect of plant population and spacings on oil content appear to be inconsistent. The oil content in the seed decreases when the unit area per plant increased (Hoag et al 1968 and Williams 1962). Peterson (1965) stated that increasing the distance between rows did not influence the oil content of the seed. However, the oil content of the seed decreased when plant population was increased in the 7-inch row. But Beech and Norman (1966) in their trial in Australia, found that oil content of the seed showed little change with increasing density. The relationship between plant spacing and oil quality is not clear but Hoag et al (1968) concluded that iodine value of oil increased as the unit area decreased.

1.5 Seed

Safflower is grown primarily for oil which is obtained from the seed. Thus the seed yield is an important aspect of safflower production

1.51 Yield

Under irrigation, safflower grown in the Great Plains of the U.S.A. produces 1750 - 2750 lb seed per acre, with a maximum yield of 4000 lb/acre (Classen & Hoffman 1950; Knowles 1955 and Purdy et al 1959). Similar seed yields are obtained in California, but with a maximum of 4800 lb/acre. In Western Australia, safflower seed yields have been reported to be in the vicinity of 3000 lb/acre (Beech 1960 and Beech and Norman 1963).

Safflower grown under non-irrigated areas tends to yield far less than the irrigated crop. The seed yields range from 350 to 1500 lb/acre (Beech 1969). The average annual yields in Queensland range from 380 to 630 lb/acre, with 1000 lb in the better areas (Harbinson 1968, Horowitz and Kleinig 1958). In India, similar yields are obtained (Chavan 1961). In the States, a reasonable seed yield of 750 - 1200 lb/acre can be expected on fallow land, but when grown after a cereal crop, seed yield is reduced to 350 - 750 lb/acre.

With sufficient soil moisture, factors affecting seed yield are date of sowing, which is largely a reflection of soil temperature (Beech 1960; Beech and Norman 1963; Knowles 1955; Luebs et al 1965 and Yermanos et al 1967), variety (Beech and Norman 1963; Nelson 1964; Rubis and Black 1958), plant population (Beech and Norman 1966; Nelson 1964;

Peterson 1965; Stern and Beech 1965), insect infestation and disease (Beech 1964; Carlson 1964; Thomas 1956), soil fertility (Beech and Norman 1967; Kapusta et al 1962; Stern and Beech 1965), soil salinity (Francois and Bernstein 1964 and Werkhoven et al 1961), and climate (Davis 1965 and Phillis 1961).

1.52 Composition

Commercially grown seeds have an average composition of oil 36 - 43%, kernel 55 - 65% and hull 33 - 45%. Experimental varieties may have a composition of oil 40 - 50%, kernel 66 - 81% and hull 18 - 30% (Rubis 1963). The present commercial varieties are far superior in their percentage oil content compared with the earlier varieties containing an average of 27 - 28% oil (Classen and Hoffman 1952; McGregor and Hay 1952 and Purdy et al 1955). The major proportion of the oil comes from the kernel and the rest from the hull. In the variety Gila for example, the p roportions of the oil are 60.0 - 61.7% and 12.6 - 13.8% for kernel and hull respectively (Beech and Norman 1963).

A number of workers have given the breakdown of the components of safflower oil (Knowles 1955 and 1965; Rubis and Black 1958; Yermanos 1967 and Weiss 1971). The major fatty acid acids are linoleic and oleic (Table 1).

Table 1 Fatty acid composition of safflower oil

Palmitic	Stearic	Oleic	Linoleic	Mis.	Non.Sapon.
6.4-7.0	2.4-2.8	9.7-18.1	76.9-80.5	0.2-0.8	0.9-1.6

Although protein is not a consideration of this study, it is interesting to note that protein is one of the main components of safflower seed. In commercial varieties, the protein component of the seed is in the range of 15.4 - 19.4% and 20.3 - 22.5% for experimental lines (Guggolz 1967).

The oil content of a particular variety of safflower is influenced by such factors as sowing date (Beech 1960; Beech and Norman 1963 and 1967; Lueb et al 1965; Nelson 1964 and Peterson 1865); soil salinity (Werkhoven et al 1966 and Yermanos et al 1964); plant population (Beech and Norman 1966; Hoag et al 1968; Peterson 1965 and Williams 1962); seed size (El Saeed 1966; and Hoag et al 1968); fertilizer treatment (Hoag et al 1968; and Yermanos et al 1964); disease (Classen and Hoffman 1950; and Thomas 1956), and insect damage (Beech 1964; Classen and Hoffman 1950; and Knowles 1955). Reports on the effect of sowing date on oil content is variable. In some cases, delay in sowing reduces oil content and in others increases. This is possibly caused by above-optimum temperatures for grain yields in the former case (Beech and Norman 1963); and below optimum temperatures in the latter (Knowles 1955; Luebs et al 1965 and Yermanos et al 1967). Canvin (1965) working with temperature range of 10°C to 26.5°C established that temperature had no effect on oil content and oil composition in terms of saturated fatty acids but the protein content increased with increasing temperature. Thus the importance of sowing date is in its relation to soil temperature and temperature at flowering. Moderate temperatures of 24 - 32°C at flowering improves seed yield while higher temperature above this level tend to lower seed yield and decrease oil content (Knowles and Miller 1965; and Weiss 1971).

Under conditions of high soil salinity, crop yield become uneconomic due to a combination of lower oil content and lower seed weight. On per unit area basis, oil yield may be reduced as much as 60% depending on variety. Gila for example, is more susceptible to saline conditions than N-10 or US10. It is possible to establish the correlation between rate of reduction of seed oil % and increasing salinity. For each millimhos per centimeter increase in soil salinity (ECe), the average oil percentage decreases by about 0.4%. Although soil salinity does not affect the chemical composition of oil, it does depress the protein content (Werkhoven et al 1966 and Yermanos et al 1964).

Fertilizer applications appear to give conflicting results in that some trials show a decrease in oil content while others show no change (Hoag et al 1968; Werkhoven 1968; and Werkhoven and Massentini 1967). Also the iodine value of the oil is not affected by fertilizers (Werkhoven 1968).

1.53 Viability

In general, seed becomes viable four days after flowering and reaches maximum viability in 14 - 16 days after flowering (Leininger and Urie 1964). At harvest, the viability of safflower seed is 95% or higher, and to maintain this viability in storage, the seed moisture content should be between 5 to 8% (James et al 1967). In U.S.A., for both registered and certified safflower seed, the minimum viability requirement is 90% (Knowles and Miller 1965).

1.54 Utilization

Safflower is grown primarily for oil. The oil is used in industries as a drying oil for paints, varnishes and alkyd resins for its rapid drying, non-yellowing and colour-retaining properties. It is also used as a high quality cooking oil and for margarine, mayonnaise and salad oil manufacture (Knowles and Miller 1960 and Weiss 1971).

Safflower meal can be prepared in two ways, viz one undecorticated meal with protein content of 19% and the other is the decorticated meal containing 36% protein. (Baker et al 1951 and 1959 and Knowles 1955). Undecorticated meal is a useful animal feed for cattle, but less suitable for poultry and pig owing to its fibre content (Baker et al 1951 and 1959; Dennis and Rubis 1966; Heineman 1953; Peterson et al 1957). Decorticated meal is suitable for ruminants, and poultry provided lysine and methionine are included (Young and Halloran 1962, and Zablan et al 1963).