VARIABILITY ANALYSIS, PHENOTYPIC AND GENOTYPIC CORRELATIONS IN SELECTED GENOTYPES OF SUNFLOWER (Helianthus animus L.)

BY

YAHAYA ABDULLAHI

A thesis submitted to the Post-Graduate School, Ahmadu Bello University, Zaria, Nigeria in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (CROP BREEDING)

Department of Plant Science,
Faculty of Agriculture,
Ahmadu Bello University, Zaria.

JULY, 1997

DECLARATION

I hereby declare that the work presented in this thesis has been composed by myself and is a documentation of my research findings. It has not been presented before in any previous application for a higher degree.

Abdullahi Ibn Yahaya
(Student)

Date: 01-12-2000

Dr (Mrs) P.E. Olorunju
(Chairperson, Supervisory Committee)

Date: 1-12-2000

CERTIFICATION

This thesis entitled "VARIABILITY ANALYSIS, PHENOTYPIC AND GENOTYPIC CORRELATIONS IN SELECTED GENOTYPES OF SUNFLOWER (Helianthus annuus L.)" meets the regulations governing the award of the degree of Master of Science (Crop breeding) of Ahmadu Bello University and is approved for its scientific contribution to knowledge and literary presentation.

Dr (Mrs) P.E. Olorunju
Chairperson, Supervisory Committee

Dr S.G. Ado
Member, Supervisory Committee

Mr F.C. Orakwue
Member, Supervisory Committee

Dr. S.G. Ado
Head, Plant Science Department

Prof. S.B. Ojo
Dean, Postgraduate School

21/03/01
Date

AHMADU BELLO UNIVERSITY, ZARIA.

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to Dr. (Mrs) P.E. Olorunju and Dr. S.G. Ado, for their major role in supervising this work.

I also wish to acknowledge with gratitude Mr. F. C. Orakwe, Drs. S.O. Alabi and C.A. Echekwu for their helpful suggestions, constructive criticisms and valuable advice in the preparation of this manuscript.

My special appreciation is extended to the entire staff of Plant Science Department especially Messrs Ahiaba, A.A. Zaria and D.A. Aba for their assistance and cooperation.

I wish to acknowledge the assistance rendered by the entire technical staff and labourers of Plant Breeding Section; the entire teaching and technical staff of the Departments of Plant Science and Agronomy, Agricultural Library and Data Processing Unit of the Institute for Agricultural Research (ABU).

Lastly, I am grateful to my mother, sisters, Hussaina and Turai for their understanding, patience and love shown to me while studying.

To my elder brothers Hassan, Hussaini and Lawal with whom I shared my curious moments, I shall always remain most grateful for their love, care, advice and encouragement.

Also the incalculable support of my wife Zainab and my little son Shamsuddeen, is most gratefully acknowledged.

ABSTRACT

Investigations to determine the phenotypic and genotypic correlations among 12 traits of sunflower (Helianthus annuus L.) were carried out for 2 years, 1992 and 1993 in Samaru, Northern Nigeria. Nine open pollinating sunflower genotypes collected from different parts of the world were grown in a randomized complete block design with four replications. Each plot consisted of four rows and the two inner rows formed the net plot from which various traits were measured and analysed.

Variations observed within the traits and between the traits were highly significant. Number of leaves per plant, capitulum diameter, plant height and grain yield exhibited a high level of variability, indicating the possibility of their improvement through appropriate breeding procedures.

The correlation studies indicated that there is an ample opportunity for improving grain yield through its components viz: emergence count, capitulum diameter, number of leaves per plant, 1000 grain weight, protein content and dry matter content. Continuous selection for these traits will therefore lead to an increase in grain yield.

Several of the methods of recurrent selection used for hybrid development eg S_1 selection, full sib and half sib could be applied as breeding strategies to improve yield and combining ability of populations. A relatively good output of oil and protein content of the grains was obtained which could be exploited to make up the prevailing nutritional deficiencies of the society.

A relatively good output of oil and protein content of the grains was obtained which could be exploited to make up the prevailing nutritional deficiencies of the society.

TABLE OF CONTENTS

Page

Title i

Declaration ii

Certification iii

Acknowledgement iv

Abstract v

Table of Contents vi

List of Tables vii

CHAPTER ONE

INTRODUCTION 1

CHAPTER TWO: REVIEW OF LITERATURE

2.1 Genetic variability 3

2.2 Heritability 4

2.3 Expected genetic advance 5

2.4 Breeding efforts 6

2.5 Oil content and quality 8

2.6 Protein content and quality 9

2.7 Correlation studies 11

CHAPTER THREE: MATERIALS AND METHODS

3.1 Genetic materials 22

3.2 Experimental site 23

3.3 Layout and cultural practices 23

3.4 Data collection 24

3.5 Statistical analyses 26

3.6 Estimation of variance components 27

3.7 Heritability 32

3.8 Correlation 34

CHAPTER FOUR: RESULTS

4.1 Mean performance 37

4.2 Estimates of variance components 48

4.3 Correlation 52

CHAPTER FIVE: DISCUSSION

5.1 Mean performance 60

5.2 Estimates of variance components 61

5.3 Correlation 65

CHAPTER SIX: SUMMARY AND CONCLUSION 68

REFERENCES 70

LIST OF TABLES

Table		Page
1.	Descriptions of the genetic materials	22
2.	Form of Analysis of variance with expected mean squares in one year for each treatment	28
3.	Form of combined analysis of variance with expected mean squares for each character	29
4.	Form of analysis of variance and covariance for two traits (a and b)	36
5.	Mean, standard error, range and coefficient of variation across two years	38
6.	Mean performance of nine varieties grown at Samaru in 1992	39
7.	Mean performance of nine varieties grown at Samaru in 1993	40
8.	Mean performance of nine varieties grown at Samaru for two consecutive years	41
9.	Comparison of means to test for significant difference	42
10.	Estimates of variance components for nine sunflower varieties grown in Samaru 1992	45
11.	Estimates of variance components for nine sunflower varieties grown in Samaru 1993	46
12.	Combined Estimates of variance components of nine sunflower varieties grown in Samaru	47
13.	Genotypic, phenotypic and environmental variance estimates	49
14.	Estimates of Genetic coefficient of variability	51

15. Genotypic and phenotypic coefficients of correlation (1992) 53

16. Genotypic and phenotypic coefficients of correlation (1993) 56

17. Genotypic and phenotypic coefficients of correlation (1992/1993) 57

CHAPTER I

INTRODUCTION

The cultivated sunflower (Helianthus annuus L.) is a native of North America primarily the Great Plains regions of U.S.A. from Nebraska to Northern Mexico and belongs to a large family of flowering plants which are mainly herbs and shrubs (Benson, 1959 and Wolfe, 1959). The crop can be cultivated everywhere in the tropics and subtropics where rainfall is not much especially during flowering and seed formation (Carter, 1978, El-Baradi, 1973 and Anon, 1982). According to Fehr (1987), sunflower is grown mainly for its oil and now ranks second to soybean among all oilseed crops in the world as a source of edible vegetable oil. Sunflower could be regarded as a relatively new crop in Nigeria with vast untapped potentials.

In countries where sunflower is grown, the primary breeding objectives have been to improve grain yield, harvest index, disease and insect resistance, or to enhance early maturity, high oil content, high protein content, oil quality, protein quality, and development of ideotypes for specific environments.

In any breeding programme, the plant breeder aims at selecting superior genotypes that constitute an improved or agronomically useful population. Many agronomic and quality traits are quantitative in nature and complex in inheritance, and often involve several related characters. For these reasons, a sound knowledge of the relationships, or nature and magnitude of associations of characters that show low heritability or are difficult to measure is very important. This is because direct selection based on the phenotypic performance of yield, a polygenically controlled complex

character, is usually not very effective and might be unreliable, but that based on its components could be more effective (Waldia et al., 1980).

Furthermore, variability in terms of yield and its components is a function of climatic conditions (Earle et al., 1968). Consequently the objectives of the study are:-

1. To evaluate the performance of selected genotypes for agronomic characters, yield, yield components and quality attributes.
2. To estimate the correlations between grain yield and its components.
3. To propose relevant breeding strategies for developing new varieties of the crop.

CHAPTER II

LITERATURE REVIEW

Genetic Variability

In plant breeding, variability which exists within and between populations is very important. More importantly is the additive genetic variability which could be exploited in crop improvement programmes. Information about genetic variance and heritability in sunflower has been reported by many authors among whom are Kovacik and Skaloud, 1979; Luczkiewicz, 1973; Marinkovic, 1982; Omran et al., 1976; Pathak, 1974; Putt, 1966; Roathe, et al., 1982 and Shabana, 1974.

According to Vranceanu and Stoenescu (1985), open pollinated varieties of sunflower would be more useful than hybrids for the characters that had no significant mean squares. However, for characters that had significant mean squares, hybrid varieties would produce more extreme values than population varieties.

In a study of a variety, Vniimk 8931 by Schuster and Kubler (1983), it was observed that the differences between the two inbred generations were small in relation to the mean values and variation range of individual values. A small decrease of oil content in kernels could be established and was accompanied by an increase in protein content in kernels. Also, variations for protein content were not so distinct like those for oil content. Gomzalez and Angeles (1986), reported that a broad genetic variability existed in the hybrids in respect of yield, days to flowering, and capitulum diameter for both achene yield and oil percentage. Rincon and Pallafox (1986), observed that the additive genetic variance was greater than the non additive variance for both achene yield

and oil percentage. Similarly, Alam et al., (1988) while studying six characters in 32 selected genotypes found that analysis of variance revealed significant variations in all characters except days to maturity. Furthermore, the genotypic coefficients of variation were low in all the characters. Mean oil content in Peredovik (Vanguard) and its progeny was within a range of variation of 44.3 - 53.1% (Piskov, 1983).

Heritability

In plant breeding a knowledge of the proportion of observed total variation that is genetic is important in terms of production of more desirable varieties. According to Burton and Devane (1963), heritability is a measure for efficiency of selection system in separating genotypes. For characters with low heritability, it will be more appropriate to use a selection method that gives as much information as possible about each selected material (eg S_1 selection). Fick (1978), reported that heritability of seed yield is relatively low compared to other agronomic traits. Kloczowski (1975) found that heritability in the broadsense on a single plant basis was 18% for yield as compared to a range of 22 to 49% for plant height, weight of 1000 grains, grain oil percentage, hull percentage of grains, and capitulum diameter. Shabana (1974) reported a relatively high broad sense heritability of 69% for grain yield among individual plants, an estimate that was similar to those for oil percentage and 1,000 grain weight, but considerably less than the estimates for days to flowering, leaf area, number of leaves per plant, plant height, and number of grains per head. Pathak (1974) obtained a broadsense estimate for yield of 57% compared to values ranging from 20 to 81% for plant height, capitulum diameter

stem diameter, 1000 grain weight, and kernel percentage. Anaschenko (1974), found that the heritability of general combining ability is high, ranging from 60 to 86%. Sychev (1986), observed a high degree of heritability from the ratio of characters inherent in the luxuriant stands to the corresponding depressed stands. Furthermore, grain yield per plant had the highest heritability value. Subsequent findings by Dilruba et al., (1988), revealed that genotypic coefficient of variability and broadsense heritability were high for yield per plant, 500 grain weight and head weight.

Expected genetic advance

Genetic advance is an index of assessing genetic improvement for selection of superior cultivars. The methods used up to now for estimating the genetic potential for yield improvement and determining yield trends are more or less relative, because of the difficulties encountered in removing environmental effects. According to a study by Vranceanu et al., (1987), genetic increases of hybrid sunflower yielding ability and oil content had slow annual rates and the trends in certain periods appeared to near a Plateau, especially in areas where environmental constraints were largest and the yield base the lowest or where long term check variety proved to be better. Similarly Chaudhary and Anand (1987), found that in general, characters showing the greatest genetic advance such as grain yield, showed the greatest variability. On comparison with the control variety Records, Vranceanu and Pirvu (1990), also observed that as a result of breeding for heterosis on the basis of inbred lines, an annual rate of increase of 1.17% for achene yield, 0.47% for oil content and 21.14% for degree of self-fertility were

obtained. However, of the over 2,500 interline hybrids studied by Stoyanova et al., (1978), 90% had marked heterosis and only 3% exceeded the standard Peredovic (Vanguard) in oil yield per hectare. Dilruba et al., (1988), also found that genetic advance was high for yield per plant and plant height.

Breeding efforts

The first breeding efforts to improve sunflower for cultivation was by the early Ozark Bluff dwellers in North America (Fick, 1978). However, the most successful early breeding programme, was that of Pustovoit (1965) in the former U.S.S.R, who increased oil percentage of commercial cultivars to 40-45%. The method he used is based on individual selection combined with maintenance of reserve seed through selection cycle. Owing to this method, resistance to broomrape (Orobanche cumana Wallr), rust and sunflower head moth (Homoesoma nebuelella H.b), were incorporated in the sunflower varieties.

Putt (1978) in Canada developed shorter early maturing cultivars in the 1940's. Resistance to rust was further incorporated into new cultivars from wild species. The other crop species such as maize (Zea mays L.) stimulated sunflower researchers to find or develop a similar system to economically produce hybrid seed. Consequently, several workers including Kinnman and Putt developed a hybrid production scheme based on self incompatibility system (Fick, 1978). The method was somewhat successful, resulting in a high percentage of hybrid seed produced on the female parent, but the hybrid percentage was highly variable depending on lines or cultivars used and the

environmental conditions at flowering.

Vranceanu (1974), in Romania developed a unique system for producing hybrid-seed utilizing genetic male sterile lines. The genetic fertile line was identified by linkage with a red anthocyanin plant pigment. By crossing the heterozygous fertile MSms (red) with the male sterile MSms (green) plants grown from seed harvested from the male sterile would segregate in the ratio 1:1 for male fertile (red) and the male sterile (green) plants. The red pigmented plants were removed before pollen shedding in hybrid production fields. The male sterile plants were pollinated by a male parent. The labour requirement to remove fertile plants was quite high which increased the cost of hybrid seed. Leclerq (1969), in France reported finding cytoplasmic male sterility in the progenies of a cross between Helianthus petiolaris Wutt and cultivated sunflower. Resultant crosses with fertile cultivated sunflower plants produced progenies that also were sterile, thus providing a stable cytoplasmic male sterile (C.M.S.) line. In Texas, Kinnman (1970), obtained the C.M.S. source from Leclerq and discovered genetic fertility restoring genes in lines that were also derived from wild species crosses. Leclerq (1971), Ennes et al., (1970), and Vranceanu and Stoenescu (1971), also reported fertility restoring genes. Thus the two factors necessary for the cytoplasmic nuclear system of hybrid seed production were found and distributed among the breeding programmes of the world. The first hybrids produced by this system were made available for commercial production in the United States of America in 1972. By 1976, hybrids were produce on over 80% of the sunflower production area (Fehr, 1987).

Oil content and quality

Oil percentage generally is considered to be quantitatively inherited (Gundaev, 1971). The breeding of Russian short-stemmed, single headed cultivars has resulted in 50% increase in oil content of sunflower (Rehm and Espig, 1991).

In a study of oil content in different types of sunflower hybrids, Petakov, (1992) found that the double cross hybrids possess a higher oil content and are less influenced by the growing conditions in comparison with the single and three-way ones. The mean values for oil content were 42.7%, 43.7% and 45.0% for the single, three-way and double cross hybrids, respectively. According to Char and Dasgupta (1977), sunflower seeds contain 40-50% high quality oil. Moreover, the result of Skoric and Marinkovic (1986) indicates that it is feasible to develop sunflower lines and hybrids possessing over 55-60% of oil. Picq and Abramousky (1992) reported an increase in oil content from 44% to 51%.

In spite of the fact that for many years a lot of work was put into the study of the inheritance of fatty acids composition of oil (Putt et al., 1969; Fick, 1975; Skoric et al., 1978; Andrich et al., 1984 and Fernandez - Martinez and Alba, 1984), it is only a couple of decades ago that the oil quality in sunflower has assumed such a great interest. This is because a diet rich in non-saturated fatty acids seem to reduce plasma cholesterol which is a risk factor for coronary heart disease (Grundy, 1986). Breeders working in various parts of the world obtained genotypes of sunflower with high oleic acid content (able to give more than 80%) basing their research on an old variety "Pervenets" (Soldatov, 1976 and Fick 1984). This variety having a grain yield less than the current

commercial hybrids was used to transfer its quality characters into the best inbred lines selected by breeders. Although the high oleic acid content was derived from the same germplasm, some differences, were found from the genetic control studies (Urie 1985; Miller et al., 1987), indicating a strong environmental interaction and presence of a modifier gene (Fehr, 1987).

Protein content and quality

According to Earle et al (1968) and Gundaev (1971), the protein percentage of cultivated sunflower seeds varies from 9 to 24%, although large numbers of different cultivars or lines were not analysed. Protein percentage of wild species generally are higher than the cultivated types (Georgieva-Todorova, and Hristova, 1975). The protein content in the F_1 of crosses of different types is intermediate or tending towards the low protein parent (Stoyanova and Ivanov 1975).

Skoric et al., (1978), found that beside differences in total content of proteins, the genotypes they tested differed also in protein components (albumin, globulin, glutenin and the alcohol fraction). The tested genotypes showed the highest variability in the quality of albumin. Bedov and Skoric (1981) concluded for the examined breeding materials of diverse genetic origin, that the protein content in seed ranged from 16 to 29%. The examined lines differed not only in total protein content, but also in the components of quality especially the content of amino acids.

Ivanov (1974), reported that the highest protein content in kernel (40%) was found in lines derived from variety Donskoy. The highest values of lysine and

methionine contents were obtained in lines derived from variety Peredovik, but the highest value for tryptophan content was detected in a line coming from variety "Mayak". A significant cultivar differences in amino acid composition of the protein was reported by Sosulski and Sarwar 1973, and Robinson 1975. Among several amino acids essential for human nutrition, Ivanov (1974), reported a range of values 1.88 to 4.00% for lysine, 3.42 to 6.25% for methionine and 0.79 to 1.32% for tryptophan in inbred lines selected from different cultivars. In a later study Ivanov (1975) identified several lines with lysine content as high as 5.20% of the protein. Also while studying several A, B and R lines, Bedov (1982), found different protein contents in the grains of these lines. Furthermore, a limited number of lines had equal protein contents in seed in the two research years. The lines differed also on the composition of amino acids. The contents of all amino acids save methionine increased together with increases in the protein content in seeds. Stoyanova and Ivanov (1975), reported that development of high protein inbreds and hybrids as long as hull amounts remained constant seemed to be possible. They also found that when crossing lines with different protein contents in seed, the inheritance of protein content in F_1 generation was intermediate. Similar results were obtained by Bedov (1985). Besides protein content, it is important to direct breeding programmes towards increases in certain protein fractions (Fernandez-Martinez and Alba, 1984). They supposed that the ratio of albumins to globulins mentioned as a criterion of selection for sunflower protein can be modified by selection.

Correlation studies

In genetic studies, two causes of correlation between characters are generally recognised: genetic and environmental. The genetic cause of correlation is chiefly pleiotropy and linkage disequilibrium. Pleiotropism occurs when one gene affects simultaneously several physiological pathways, resulting in influence over several observed characters. Negative correlations between characters may lead to selection of cultivars with undesirable characters. Linkage refers to genes located on the same chromosome with a tendency of being transmitted together. If a negative association effects, it would be difficult to obtain desired combinations, while if linkage is involved, special breeding programmes are needed to break this linkage (Al-jibouri et al., 1958; Pandy and Gritton 1975; Hallauer and Miranda 1981). Grain yield in sunflower is a quantitative character and is largely dependent on its own component characters (Punia and Gill, 1994).

Yield components and their relationships

Days to flower

Russel (1949) reported that the correlations between yield inbreds and characters such as days to flowering and days to maturity were positive and highly significant. These results are in agreements with those earlier reported by Putt (1943). Also while studying some of the morphological characters and their relationships to yield, Ross (1939), found a highly significant and negative correlation coefficient between seed yield and days to blooming. Similarly Schuster (1964), found a negative relationship between seed yield and days from sowing to blooming. However, a significant positive

correlation coefficient between days to flowering and seed oil percentage of some inbred lines and their top cross hybrids was observed by Russel (1953).

Maturity

Tanimu and Ado (1988), reported highly significant positive correlations between days to maturity and stem diameter. Correlation studies (Ross, 1939; Putt, 1943; Natali, and Shaikh, 1970; Fick et al., 1974; Kumar, 1976 and Singh et al., 1977) revealed that by and large yield was positively correlated with days to maturity. It was also reported by Misra et al., (1985), that days to maturity is a component having high positive and significant relationship with yield. Kumar (1976), identified days to maturity, plant height, stem diameter and 1000 grain weight as major components that determine variability in grain yield (about 70% of variation in yield could be explained by taking these characters). Days to maturity was also found to be significantly and positively correlated with plant height indicating that taller plants matured later (Rana et al., 1991).

Grain yield

Ado et al., (1987), found a positive correlation between grain yield and number of leaves per plant. The correlations between seed yield and plant height, head diameter and days to maturity were negative. These results contradict those earlier reported by Putt (1943), who found a positive correlation between grain yield and plant height, head diameter and days from sowing to maturity. However, Foti and Abbate (1982), reported that the number of grains per cm^2 of fertile inflorescence area, was inversely related to grain yield per plant, which was highly positively correlated to 1000 grain weight and

both were negatively correlated with oil content. Giriraz et al., (1979), also found a significant and positive phenotypic correlation between grain yield and head diameter, 1000 grain weight, plant height and number of leaves per plant in 392 elite lines of sunflower variety E.C. 68415. These results are in close agreement with those obtained by Pathak and Dixit (1984). Also, Punia and Gill (1994), observed that grain yield per plant was positively and significantly correlated with the following characters viz: plant height (0.6571), stem diameter (0.5267), head diameter (0.8392), 1000 grain weight (0.9125), and number of grains per head (0.9428).

However, grain yield was found to be negatively and significantly associated with unfilled seed percentage (-0.6790), indicating that percentage of unfilled heads is also an important component of grain yield. These findings support the earlier observations of Putt (1943); Pathak (1974); Skoric (1974); Varshney and Singh (1977); Alba and Greco (1979) and Marinkovic (1992). Alba et al., (1979), observed a negative correlation between grain yield and head diameter and a positive but non significant correlation between grain yield and 1000 grain weight. Moreover, Varshney and Singh (1977) had found non significant correlations between grain yield and head diameter. Ivanov and Stoyanova (1980), indicated that only plant height, kernel and 1000 seed mass had positive relationship with yield. Conversely, Dua and Yadava (1985), reported that plant height, stem diameter and head diameter were the most important attributes of grain yield per plant and that these characters appeared to be governed by some pleiotropic effects. Kovacik and Skaloud (1979), found high correlations between yield and number of grains per plant. Similar results were reported by Putt (1943) and Shabana (1974). Significant

positive correlations between grain yield and 1000 grain mass were obtained by a number of scientists (Pathak, 1974; Shabana, 1974; Stoyanova et al., 1975; Varshney, and Singh, 1977; Alba and Greco, 1979 and Tyagi, 1985).

Head size and weight

Preliminary trials conducted by Burns (1970), using seeds of variety "Peredovik" gave good correlation between seed yield and head size, but poor correlation with weight of threshed seed. Further studies revealed that large heads had heavier seeds than smaller heads. Highest correlation between yield and its components was found between yield and head diameter (Velkov, 1980). Giriraz et al., (1979), also reported significant positive phenotypic correlations between seed yield and head diameter in 395 elite lines of sunflower variety E.C. 68415. These findings conform to those obtained by Pathak and Dixit (1984). Similarly Alba and Greco (1979), found a significant correlation between grain yield and two yield components viz head diameter and plant height. However, the head diameter exhibited the highest correlation coefficient (+ 0.78) with seed yield. Similar results were obtained by Shabana (1974). A positive association between head diameter and stem diameter, and plant height and head diameter, was reported by several scholars (Ross, 1939; Putt, 1943; Natali and Shaikh, 1970; Fick, et al., 1974; Kumar, 1976 and Singh et al., 1977). Subsequent investigations by Khan et al., (1989), have also shown that there were positive correlations between yield and yield components and that head size was highly correlated with seed yield. These findings lend credence to that reported by Caylak and Emiroglusit (1964), that head yield was

strongly correlated with head diameter. Venturi et al., (1981) also reported that head diameter was significantly and positively correlated with seed yield which is quite logical, since the bigger the head size, the more the seeds and thus the higher the yield. Similarly, Alam et al (1988), found that seed yield per plant was significantly and positively correlated with capitulum diameter and number of seeds per capitulum. Similar relationships were observed by Tanimu and Ado (1988).

Plant height

It was reported by Chandra and Anand (1977), that yield was phenotypically and genotypically positively correlated with plant height. However, a significant positive correlation was found between seed yield and plant height (Varshney and Singh, 1977 and Skoric, 1974).

Asawa (1977), also identified plant height and filling percentage in seeds as the most important characters governing variability in yield. Similarly, Basudeo et al., (1977), found that yield was positively correlated with plant height at both genotypic and phenotypic levels. These results corroborate the findings of Ross (1939). Other researchers like Punia and Gill (1994) reported similar findings. Moreover, Kumar (1976) observed that plant height was among the major components that determined variability in seed yield. However, Dua and Yadava (1985), identified plant height, stem diameter and head diameter as the most important attributes of seed yield per plant.

Stem girth

Investigations carried out by Khanna (1972), indicated that there was a negative correlation between the percentage seed set and capitulum and stem diameter. Vanisree et al., (1980), reported that stem diameter was positively and highly significantly correlated with yield. Similarly Sherriff et al., (1987) identified stem circumference and dry matter content as characters most closely related to seed yield. Furthermore, the results obtained by Niranjana and Shambulingap (1989), showed that yield could be improved by increasing stem circumference. The joint interaction of stem and capitulum diameter appears to be important in determining seed set (Khanna, 1992). Correlation studies conducted by Larshmanaiah (1980), showed that seed yield and oil content were positively associated with stem girth.

1000 grain weight

Singh and Singh (1977), identified yield as positively correlated with 1000 grain weight at both genotypic and phenotypic levels. Similar observations were reported by Alba and Greco (1979). Abdel-Gawad et al., (1987), reported a slightly significant correlation between grain yield and 1000 grain weight under irrigation condition. According to Foti and Abbate (1982), variations were determined by corresponding modification of the total fertile inflorescence and 1000 grain weight. Similarly, Suzer and Atakisi (1993), found significant correlations between head diameter and 1000 grain weight ($r = 0.224$). Furthermore, the relationship between grain number per head and 1000 grain weight was significant ($r = 0.34$). Comparable results were reported by

Miller et al., (1984) and Majid and Scheneiter (1987). Sunflower seed yield according to Morozou (1970), could be increased significantly by breeding for seed size; that is higher values of 1000 seed mass. According to him, the increase in 1000 seed mass by only one hectoliter mass brings increases in seed yield of 40 kg/ha. Also the genetic correlations of yield per 1000 seed and yield per kernel were negative as reported by Ivanov and Stoyanova (1980).

Number of grains per head and 1000 grain weight are the main grain yield components (Singh and Labana 1990; Viscic 1991 and Marinkovic 1992). A positive correlation between seed yield and hectoliter mass was also obtained by many authors (Pathak, 1974; Shabana, 1974; Stoyanova et al., 1975 and Tyagi 1985). According to Shabana (1974), the main role in seed forming with sunflower varieties is played by 1000 grain mass; the second and third most important parameters are seed number per head and the main height of plant. Having found that 1000 grain mass was not in correlation with all characters, but that it was invariably in correlation with grain yield, Shabana concluded that breeding for high 1000 grain mass is important in the development of high yielding hybrids. However, Pathak et al., (1987), while studying the correlations of seed yield and nine related characters, found that 1000 achene weight was phenotypically and genotypically independent of other characters indicating its minor role in crop improvement.

Oil content and quality

The oil content of 4 hybrids studied by Suzer and Atakisi (1993), increased approximately by 3.8% as the plant population was increased from low to high. Besides, there was a significant correlation between plant population and oil content (r = 0.234). Similar findings were reported by Harmati (1990) and Schneiter et al., (1992). Also Vanozzi et al., (1986) found that achene yield was closely correlated with oil yield. Earlier studies by Fick (1984), have also indicated the existence of a highly significant but negative correlation between oil content and seed weight. Similarly Alba and Greco (1979), observed that the correlation, of oil and seed yield were too low and therefore not significant. In other words oil content showed a positive and non significant correlation with yield (+ 0.43). Omran et al., (1979) also reported a negative correlation between seed yield per plant, 1000 seed weight and oil content. However, Picq and Abramousky (1992), revealed a positive correlation between oil content and yield although there was a strong varietal effect and oil contents could vary widely for a given yield. Stoyanova and Ivanov (1975), established the existence of highly positive correlations for oil content in seed between parent lines and their hybrids (r = 0.71). A positive correlation exists between rate of germinating seeds and oil content (Popova, 1978). Faster growth rate was found to be associated with increase in oil content. However, seed oil content and yield were not significantly correlated with leaf characteristics as studied by Vagvolgyi (1989). Nevertheless, a significant negative correlation between 1000 grain weight and oil content in seed was observed by Suzer and Atakisi (1993). Similar results were reported by Robinson et al., (1980) and Stanojevic

(1989). In a study conducted by Punia and Gill (1994), it was observed that oil content was not all correlated with any of the characters studied indicating that it was an entirely independent component of all characters studied including seed yield. They consequently opined that oil content could be improved along with other seed yield components without any compromise. Fick et al., (1974), obtained a highly significant negative correlation between oil content and seed yield. Also, the correlations of oil percentage with agronomic characters such as seed yield, plant height, head diameter, maturity and leaf area have not been consistent as reported by Carter (1978). According to Skoric (1974), plant height was positively correlated with oil yield in a group of hybrids studied, while number of leaves per plant was positively correlated with oil yield in another group. However, oil yield was negatively correlated with percentage of husks in all the groups tested. In addition, different correlations existed between the contents of certain fatty acids in sunflower; significant negative correlations were found between linoleic and oleic acids. A strong genetic and phenotypic negative correlation between the oleic and linoleic acid contents in seed oil similar to the positive correlation between linoleic and palmitic acid contents was found by Skoric et al., (1978) and Skoric et al., (1982). Schuster (1964), obtained a highly significant positive correlation between the oil content in F_1 hybrids and the female lines while the correlations with male lines were insignificant.

Protein content

Sidhu and Bains (1980), observed a positive correlation between seed protein and germinability in seeds. Seed protein was negatively correlated with days to flowering and seed oil content. Similarly Marinescu (1980), reported a negative correlation between oil and protein contents. Loubser and Grimbeek (1963), also found that increase in protein content was associated with increase in nitrogen rate with sunflower cultivar 722 and that oil increment was significant. However, increasing nitrogen rate only led to a decrease in oil-protein ratio from 2.51:1 to 2.06:1. A corresponding result was obtained by Appelqvist (1978), who reported that increase in nitrogen generally decreased seed oil content and increased the protein content. Similarly, Alba and Greco (1979), found that correlations of oil and protein with seed yield were too low and non significant. According to Bedov, (1985), a significant negative correlation between oil content and protein in seeds exists and that this has been found by many researchers. Djakov (1986), proved experimentally the negative correlations between oil content and protein content. Bedov and Skoric (1981), stated that increases in protein content brings simultaneous increase of most amino acids as well as lysine.

Other characters

Giriraz et al., (1979), identified a significant and positive phenotypic correlation between seed yield and number of leaves per plant. Similar results were obtained by Pathak and Dixit (1984). Potdar et al., (1977), in trials with sunflower cultivar EC6841 observed that seed yield was positively correlated with number of functional leaves and

filled seeds per plant. Correlations between number of achenes and florets per capitulum were found to be high (r = 0.60 - 0.95) (Voskobolnik and Marin 1989). However, Pathak (1974) observed significant positive correlations between seed yield per plant and the following characters: total dry matter, plant height, stem diameter, head diameter, 1000 seed mass (kernels) and the mass of husks.

CHAPTER III

MATERIALS AND METHODS

Background of genetic materials studied

The genetic materials used for the present investigations consisted of nine open pollinating sunflower varieties, of which eight were exotic and one local as shown in Table 1.

Table 1: Descriptions of the nine open pollinating sunflower varieties

S/No.	Variety	Source	Characteristics
1	Funtua	Nigeria	Ovoid, wide shape seeds, plant height (1.90m) stem diameter (2.23cm), capitulum diameter (24.25cm, grain yield (1.82 t/ha), days to maturity (97), protein content (28%), oil content (35%).
2	Isaanka	Kenya	Ovoid dark brown seeds, plant height (1.62m), capitulum diameter (28.00cm), stem diameter (2.05cm), grain yield per ha (1.42 t/ha), days to maturity (87), protein content (28%), oil content (32%).
3	Peredovik	Canada	Ovoid wide shape seeds, plant height (1.90m),capitulum diameter (23.75cm), stem diameter (2.10cm), grain yield per ha (1.22 t/ha), days to maturity (97), protein content (27%), oil content (24%).
4	Record	Romania	Ovoid wide shape seeds, plant height (1.40m), capitulum diameter (16.00cm), days to maturity (94), grain yield per ha (1.54 t/ha), protein content (26%), oil content (25%).
5	Saturn	Canada	Brown ovoid seeds, plant height (1.49m), grain yield per ha (0.85 t/ha), days to maturity (99), protein content (29%), oil content (31%).
6	Smena	Canada	Wide brown seeds plant height (1.89m), stem diameter (2.20cm), capitulum diameter (27.50cm), grain yield per ha (2.61 t/ha), days to maturity (92), protein content (28%), oil content (33%).
7	Vniimk8883	Canada	Brown seeds, plant height (1.79m), stem diameter (1.60cm), capitulum diameter (20.00cm), days to maturity (88), grain yield per ha (1.65 t/ha), protein content (29%), oil content (29%).
8	Cakinskij 268	Canada	Wide brown seeds, plant height (1.68m), stem diameter (1.73cm), capitulum diameter (20.00cm), days to maturity (96) grain yield per ha (1.18 t/ha), protein content (26%), oil content (31%).
9	Chernianka 66	Canada	Ovoid brown seeds, plant height (1.35m), stem diameter (1.73cm), capitulum diameter (20.25cm), grain yield per ha (1-13 t/ha), days to maturity (88), protein content (25%) and oil content (36%).

Experimental site

The experiment was conducted under field conditions in 1992 and 1993 at the farm of the Institute for Agricultural Research Samaru (11° 11'N; 07° 38'E), Ahmadu Bello University, Zaria.

Layout and Cultural practices

Each year the experiment was laid out in a randomized complete block design (RCBD) with four replications. Each plot consisted of four rows 75cm apart and 10 m long (30 m^2). Three seeds were sown per hill at a spacing of 25 cm per hill. The seedlings were later thinned to one plant per stand three weeks after sowing, that is (53,333 plants per ha) population density. Galex, together with Gramoxone were applied as pre-emergence herbicides at the rate of 4 litres per hectare (500 ml/20 litres of water) with Knapsack sprayer. Two supplementary hoe weedings, with the first at three weeks after sowing and the second at six weeks after sowing were done. One hundred kilogram of nitrogen in form of calcium ammonium nitrate (26%N), 50kg of phosphorus in form of single superphosphate (18% P_2O_5) and 30kg of potassium in form of muriate of potash (62% K_2O) were applied 5-10cm away from seeds at planting.

Observations

Five plants were randomly selected and tagged per plot, from which data were recorded. Data concerning grain yield 1000 grain weight, emergence count and days to 50% flowering were on per plot basis.

(A) Emergence count (percentage): This was estimated at two weeks after sowing by counting the number of stands observed per plot and dividing by the number expected.

$$\text{Emergence count (\%)} = \frac{\text{Number of seedlings observed}}{\text{Number expected}} \times 100$$

(B) Days to 50% flowering: This was recorded as the number of days when 50% of the plants in the plot showed anthesis, that is when at least half of the plants in the plot had flowered.

(C) Days to maturity: This was noted as the number of days from planting to physiological maturity (that is from sowing to the date when the back of the heads in a plot turned yellow and the outer bracts had turned brown).

(D) Plant height: The plant height was measured (to the nearest cm) from soil surface to the point where the capitulum was attached to the stem.

(E) Number of leaves per plant: The number of leaves produced in each selected plant was recorded after counting.

(F) Capitulum diameter: The capitulum (head) diameter was obtained to the nearest cm from the tagged plants and this was divided by the number of plants to obtain the average.

(G) Grain yield: The grain yield (kg/ha) was obtained after harvesting and threshing from the net plot. The grains harvested from each plot were weighed.

(H) 1000 grain weight: 1000 grains were counted from each plot after threshing and weighed using a Mettler scale model 1210 to the nearest 0.1g

(I) Oil content: Laboratory analyses were done at the Department of Animal Science, Faculty of Agriculture, A.B.U. The oil content of the grains was determined using the method described by Randall (1974). Essentially, this involved weighing 3g of oven dried samples of the grain into a tarred Whatman thimble and mixing with 0.4g of dampened asbestos, using a stainless steel spatula. The mixture was then oven-dried for one hour. Previously heated 1g of Henger granule which was dessicator cooled was added to the mixture. Also added to the mixture was 50ml of petroleum ether in an extraction flask which was connected to a condenser. The mixture was heated and the extraction continued for 30 minutes. The flask was disconnected from the condenser and the ether/oil mixture heated on a stem bath for five minutes only to evaporate the ether. The oil was cooled and weighed.

Protein Content (%) The nitrogen content of the grain was determined by the standard Micro-kjeldahl procedure (A.O.A.C. 1975). The method involved oven-drying of samples at 70°C for 24 hours and grinding to pass through 1mm sieve. From the sieved

sample, 1gm was digested sulphuric acid, copper sulphate and sodium sulphate as catalyst. The solution was distilled into boric acid and the distillate titrated against standard hydrochloric acid and the percentage nitrogen determined from the titre. The crude protein content was then determined by multiplying the nitrogen content by a factor of 6.25.

(J) Ash content (%): About 0.5g of each plot sample was weighed and inserted into a crucible. The crucible together with the samples were later placed into a Limberg furnace at a temperature of 550-600°C for 6-24 hours. The heated samples were then cooled in a desiccator for 30 minutes and finally weighed using a Mettler balance.

Statistical analyses

The experiments for the two consecutive years were laid out in a randomized complete block design (RCBD) with four replications, at two different fields (X field in 1992 and Y field in 1993) both in Samaru, Zaria.

From the data collected in each plot, for each year as well as for both years, means, standard errors, coefficient of variation and range were computed.

Mean

The arithmetic mean was calculated by dividing the total observations by their number and is denoted by

$$\bar{X}=\frac{1}{n}\left(\sum_{i=1}^{n} Y_i\right)$$

Where

$\bar{X}$ = arithmetic mean

n = number of observations

ΣY_i = total observations

ANALYSIS OF VARIANCE

From the plot means of the genotypes across the years, the analysis of variance (ANOVA) was computed.

The statistical model used for the combined anova was:

$$X_{ijk} = U + Y_i + R_{ij} + G_k + (GY)_{ik} + E_{ijk}$$

Where U = Overall mean

Y_i = the effect of the i^{th} year; i = 1,2

R_{ij} = the effect of the j^{th} replication in the i^{th} year; j = 1,2, 3,4

G_k = the effect of the k^{th} genotype;
= k = 1,2,3,.....9

$(GY)_{ik}$ = the interaction effect between k^{th} genotype in the i^{th} year

Assuming

Y_i --------- NID $(0, \sigma^2_Y)$

G_k --------- NID $(0, \sigma^2_G)$

E_{ijk}--------- NID $(0\ \sigma^2_E)$

Where

σ^2_Y = variance due to years

σ^2_G = variance due to genotypes

σ^2_E = error variance.

NID = Normally and Independently Distributed.

Table 2: Form of ANOVA with Expected Mean Squares (E.M.S.) in one year for each character

Source of variation	df	MS	E.M.S.
Replications	(r-1)		
Genotypes	(g-1)	M_g	$\sigma_e^2 + r\,\sigma^2_g$
Error	(r-1) (g-1)	M_e	σ_e^2

Where df = degree of freedom

r = number of replications

g = number of genotypes

σ_e^2 = error variance

M subcripted = the observed mean square of the subscripted effect.

From each year, components of variance were estimated from the expected mean square for each trait by using observed mean squares, thus $\sigma_e^2 = M_e$, $\sigma^2_g = \frac{(M_g - M_e)}{r}$

Combined ANOVA

A combined analysis of variance for the two years for each character provided more valid estimates of the variance components including the genotype x year interaction

Table 3: Form of combined ANOVA with Expected Mean Squares for each character.

Source of variation	df		MS	EMS
Years	(y-1)			
Replications	(r-1)			
Replications within years	y(r-1)			
Genotypes	(g-1)		M_g	$\sigma_e^2 + r\,\sigma^2_{gy} + ry\,\sigma^2_g$
Genotypes x years	(g-1)	(y-1)	M_{gy}	$\sigma_e^2 + r\,\sigma^2_{gy}$
Error	y(r-1)	(g-1)	M_e	σ_e^2

Where

y = number of years

r = number of replications

g = number of genotypes

M subcripted = observed mean square of the effect

σ^2_{gy} = genotype x year interaction variance

σ_e^2 = error variance

σ^2_g = genotypic variance.

F-test

This was done to determine if variation among genotypes and their interaction with years were significantly different from zero. The test was used for both single and combined ANOVA

$F = \frac{M_g}{M_e}$, with (g-1), (r-1) (g-1) degrees of freedom for one year

$F = \frac{M_{gy}}{M_e}$ with (g-1) (y-1), y(r-1) (g-1) degrees of freedom for two years.

Comparison of means

This was done to determine if differences among treatments were statistically significant or not. The test used was that of Duncan's Multiple Range Test (DMRT). The procedure used could be summarized under the following steps as described by Obi (1986).

1. $S_x^- = \sqrt{\frac{S^2}{r}}$

Where

S_x^- = standard error

S^2 = error mean square from ANOVA table

r = number of replications or the size of the divisor from the varietal mean under comparison.

2. Find the significant studentized Ranges (SSR) from a given table.

3. Calculate the least significant range (LSR),

$LSR = (SSR) \cdot S_x^-$

The LSR values obtained were used in comparing differences between treatment means for significance.

Estimates of variance

The components of variance and their standard errors were estimated from expected mean squares using observed mean square values of each character, thus

$$\sigma^2_e = M_e \text{ with } S.E. = \sqrt{\frac{2(M_e)^2}{df_e+2}}$$

$$\sigma^2_{gy} = \frac{M_{gy}-M_e}{r} \text{ with } S.E. = \sqrt{\left(\frac{1}{r}\right)^2\left(\frac{2(M_{gy})^2}{df_{gy}+2}+\frac{2(M_e)^2}{df_e+2}\right)}$$

$$\sigma^2_g = M_g - \frac{M_{gy}}{ry} \text{ with } S.E. = \sqrt{\left(\frac{1}{ry}\right)^2\left(\frac{2(M_g)^2}{df_g+2}+\frac{2(M_{gy})^2}{df_{gy}+2}\right)}$$

The phenotypic variation among genotypes was estimated as

$\sigma^2_{ph} = \sigma^2_g + \frac{\sigma^2}{r}$ for one year

or

$\sigma_{ph}{}^2 = \frac{M_g + M_{gy}}{ry} + M_e$

The standard error for phenotypic variance was estimated as

$$S.E.(\sigma^2_{ph}) = \sqrt{\left(\frac{1}{r}\right)^2\left(\frac{(M_g)^2}{df_g+2}\right)}$$

$$S.E.(\sigma^2_{ph}) = \sqrt{\left(\frac{1}{ry}\right)^2\left(\frac{(M_g)^2}{df_g+2}\right)}$$

Heritability

Broad sense heritability (h^2_b) estimates were calculated for each year as well as combined. The heritability was computed from variance component estimates using the formula

$$h^2_b = \frac{\sigma^2_g}{\sigma^2_{ph}} \quad \text{or}$$

$$h^2_b = \frac{\sigma^2_g}{\frac{\sigma^2}{ry} + \frac{\sigma^2_{gy}}{r} + \sigma^2_g} \quad \text{with}$$

$$S.E. = S.E. \frac{\sigma_g^2}{\sigma_{ph}^2}$$

where

h^2_b = broad sense heritability

σ^2_g = genotypic variance

σ_e^2 = environmental variance

σ^2_{gy} = components of variance due to interaction of genotype with years

r = number of replications

y = number of years

Genotypic Coefficient of Variation

The genotypic coefficient of variation (GCV) was estimated by the formula suggested by Burton (1952) and Hanson et al., (1956).

$$GCV(\%) = \frac{\sqrt{\sigma_g^2}}{\bar{X}} \times 100$$

Where

σ_g^2 = genotypic variance of a character

$\bar{X}$ = mean of the character

Expected Genetic Advance

The expected genetic advance (ΔG) under selection and the expected genetic advance in percent of mean were estimated by the methods suggested by Johnson et al., (1955b) and Burton and Devane (1963):

$$\Delta G = h^2 . K . \sigma_{ph}$$

and ΔG in % of mean = $\frac{\Delta G}{\bar{x}} \times 100$

Where ΔG = expected genetic advance

h^2 = heritability

k = selection intensity

σ_{ph} = phenotypic standard deviation among the genotypes

$\bar{x}$ = mean of character.

Correlations

Genotypic, phenotypic and error correlations were estimated for pairs of traits measured. The genotypic correlation coefficients were calculated from the components of variance and covariance. Table 4 shows the form of analysis of variance and

covariance of a pair of characters (a and b) with their expected mean cross products for two years.

The formula used was that of Mode and Robinson (1959)

$$r_{gab} = \frac{\sigma_{gab}}{\sqrt{\sigma^2_{ga} \cdot \sigma^2_{gb}}}$$

Where σ_{gab} = genotypic covariance of characters a and b

σ^2_{ga} = genotypic variance of character a

σ^2_{gb} = genotypic variance of character b

r_{gab} = genotypic correlation coefficient of characters a and b

The phenotypic correlations were computed using the mean squares and mean cross products in the formula

$$r_{ph} = \frac{M_{gab}}{\sqrt{M_{ga} \times M_{gb}}}$$

where

M_{ga} = entry mean square of character a

M_{gb} = entry mean square of character b

M_{gab} = entry mean product of character a and b

The environmental correlation coefficients were also computed for a pair of characters using the error mean squares and error covariance values. The environmental correlation is the measure of the effect of environment (year) on the association of the characters in each pair.

$$r_{eab} = \frac{\sigma_{ab}}{\sqrt{\sigma^2_a \cdot \sigma^2_b}}$$

Where r_{eab} = environmental correlation coefficient for characters a and b

σ_{ab} = environmental covariance for character a and b

σ^2_a = environmental variance for character a

σ^2_b = environmental variance for character b.

Table 4: Analysis of variance and covariance with observed expected mean products for two traits (a and b).

Source of variance	df	Trait a	Trait b	Mean Product (ab)	Expected mean product
Entries	(g-l)	M_{ga}	M_{gb}	M_{gagb}	$\sigma_{ab} + \sigma_{gyagyb} + ry\sigma_{gagb}$
Entries x years	(g-l)(y-l)	M_{gya}	M_{gyb}	M_{gyagyb}	$\sigma_{ab} + r\sigma_{gyagyb}$
Error	7(g-l)(y-l)	M_{ea}	M_{eb}	M_{eaeb}	σ_{ab}

CHAPTER IV

RESULTS

The general means and their associated standard errors, range, and coefficient of variation for the twelve characters measured for two years among the nine varieties are given in table 5. Considerable variations were observed for the different characters. The coefficient of variation ranged from 0.4% to 21.20% for grain dry matter and number of leaves, respectively. The traits which showed a high level of variation were number of leaves per plant, capitulum diameter, grain yield and plant height. Medium level was recorded for emergence count, while other characters had low values. The high coefficient of variation recorded for traits like number of leaves per plant showed that there was plant to plant variation in leaf production. Wide ranges in the means were observed for plant height, 1000 grain weight and grain yield. In all cases, the standard errors of the means were lower than the means. In general, most of the characters studied exhibited a wide range of phenotypic variation.

Varietal means

The varietal means for the characters measured for each of the nine varieties including the standard errors are given in tables 5,6 and 7 for the 1992, 1993 and 1992/93 combined, respectively. From the 1992 trials, the variety Chernianka 66 was the highest yielder (732.00 kg/ha), whereas Record gave the lowest yield of 491.00 kg/ha. However, in 1993, Smena had the highest yield (813.0kg/ha) and Record remained the poorest yielder (577.00kg/ha). When the two years data were combined,

Table 5: General mean $\bar{x}$, standard error (S.E.), range and coefficient of variation for the Twelve traits of sunflower grown for two years at Samaru.

Character	$\bar{x}$	S.E.	Range	CV%
Capitulum diameter (cm)	19.22	± 2.83	7.00 ±26.00	20.80
Plant height (cm)	141.90	±141.40	97.00±198.00	15.40
Days to 50% flowering	61.31	±1.05	54.00 ±70.00	2.40
Days to maturity	90.97	±1.29	73.00±102.00	2.00
Number of leaves per plant	24.82	±3.72	7.00±34.00	21.20
1000 grain weight (g)	70.00	±8.16	40.90±105.60	15.60
Emergence count (%)	91.50	±7.32	78.75±100.00	7.10
Grain yield (kg/ha)	657.00	±89.20	326.67±940.00	19.20
Oil content (%)	28.66	±0.37	18.80±40.20	1.80
Protein content (%)	24.53	±0.24	19.90±26.70	1.40
Dry matter content (%)	94.76	±0.24	91.11±96.80	0.40
Ash content (%)	6.21	±0.19	4.91±8.50	4.30

Table 6: Mean performance of the nine varieties of sunflower grown at Samaru in 1992

Variety	Capitulum diameter (cm)	Plant height (cm)	Days to maturity	Days to 50% flowering	Number of leaves per plant	1000 grain weight (g)	Emergence count (%)	Grain yield (kg/ha)	Oil content (%)	Protein content (%)	Dry matter content (%)	Ash content (%)
Peredovik	21.00	164.30	88.75	60.00	29.25	68.50	90.63	641.00	19.20	24.20	95.79	6.22
Cakinskij 268	17.25	155.80	74.00	58.00	21.50	60.80	90.94	503.00	27.80	22.30	95.00	5.42
Isaanka	24.00	149.30	88.00	68.00	27.50	87.10	93.31	692.00	27.60	26.20	96.10	5.33
Saturn	21.00	119.30	96.50	58.00	21.00	84.10	93.13	727.00	31.00	26.10	94.01	6.77
Funtua	15.00	124.00	93.50	57.50	29.75	79.70	91.56	717.00	29.50	24.90	95.82	6.70
Vniimk 8883	17.00	134.00	101.00	63.00	27.50	58.40	90.00	561.00	39.86	26.50	93.12	7.20
Chernianka 66	20.25	129.80	88.00	64.50	26.75	76.40	91.44	732.00	34.20	20.40	94.98	5.12
Smena	23.25	125.30	89.00	66.25	30.25	88.70	94.15	686.00	27.10	24.90	95.56	5.78
Record	16.25	136.00	88.25	56.50	2o.25	66.80	85.63	491.00	23.70	22.60	91.14	5.14
Mean	19.44	140.60	90.78	61.31	26.64	74.40	91.21	639.00	28.88	24.24	94.71	5.96
SE ±	2.58	16.55	0.89	1.08	3.66	7.68	7.68	85.10	0.44	0.24	0.33	0.24

Table 7: Mean performance of the nine varieties of sunflower grown at Samaru in 1993

Variety	Capitulum diameter (cm)	Plant height (cm)	Days to maturity	Days to 50% flowering	Number of leaves per plant	1000 grain weight (g)	Emergence count (%)	Grain yield (kg/ha)	Oil content (%)	Protein content (%)	Dry matter content (%)	Ash content (%)
Peredovik	18.00	174.00	97.25	64.50	30.50	69.40	91.88	685.00	23.20	23.80	96.15	7.18
Cakinskij 268	15.00	160.00	84.00	62.00	20.00	62.50	89.69	647.00	28.00	24.50	95.69	5.32
Isaanka	24.00	115.00	85.00	64.00	26.00	91.00	93.63	780.00	30.80	23.80	95.95	5.11
Saturn	20.00	121.00	98.75	61.50	15.50	83.80	92.38	713.00	25.60	26.20	95.95	6.47
Funtua	25.00	174.00	95.75	57.75	28.00	58.10	93.00	663.00	34.63	25.50	96.47	8.47
Vniimk 8883	19.00	143.00	88.75	57.00	24.00	70.90	90.94	620.00	32.60	26.20	92.53	6.44
Chernianka 66	12.00	114.00	84.00	61.50	15.00	74.60	93.13	587.00	31.40	24.23	96.07	6.05
Smena	25.00	148.00	93.00	68.00	30.00	97.00	92.81	813.00	29.40	25.30	94.13	6.14
Record	13.00	140.00	94.00	55.50	18.00	54.70	89.38	577.00	20.30	23.80	91.09	5.30
Mean	19.00	143.20	91.17	61.31	23.00	73.60	146.90	676.00	28.44	24.81	94.81	6.45
SE ±	3.12	15.15	1.57	1.07	3.89	7.77	7.35	94.40	0.29	0.25	0.11	0.11

Table 8: Mean performance of the nine varieties of sunflower grown at Samaru for two consecutive years

Variety	Capitulum diameter (cm)	Plant height (cm)	Days to maturity	Days to 50% flowering	Number of leaves per plant	1000 grain weight (g)	Emergence count (%)	Grain yield (kg/ha)	Oil content (%)	Protein content (%)	Dry matter content (%)	Ash content (%)
Peredovik	19.50	169.10	98.00	62.25	29.88	68.90	91.25	663.00	21.20	24.00	6.70	59.97
Cakinskij 268	16.13	157.90	79.00	60.00	20.75	61.70	90.31	575.00	27.90	23.40	5.37	95.36
Isaanka	24.00	132.10	86.50	66.00	26.75	89.00	93.44	736.00	29.20	25.00	5.52	96.07
Saturn	20.50	120.10	97.63	59.75	18.25	84.00	92.56	720.00	28.30	26.15	6.62	95.02
Funtua	20.00	149.00	94.63	57.63	28.88	68.90	92.25	690.00	32.06	25.20	7.59	94.14
Vniimk 8883	18.00	138.00	94.88	60.00	25.75	64.60	90.50	590.00	36.20	26.40	7.32	92.83
Chernianka 66	16.13	121.90	86.00	63.00	20.88	75.50	92.25	659.00	32.80	22.31	5.58	95.52
Smena	24.13	150.10	91.00	67.13	30.13	92.60	93.50	750.00	28.25	25.10	5.96	94.85
Record	14.62	138.00	91.17	56.00	22.13	60.70	87.50	534.00	28.44	23.20	5.22	94.81
Mean	19.22	14.90	90.97	61.31	24.82	74.00	91.50	657.00	28.66	24.53	6.21	94.76
SE ±	2.00	10.95	0.91	0.74	2.64	5.77	5.18	63.1	0.26	0.17	0.13	0.17

Table 9: Varietal means of the twelve traits of sunflower grown for two years at Samaru

Variety	Capitulum diameter (cm)	Plant height (cm)	Days to maturity	Days to 50% flowering	Number of leaves per plant	1000 grain weight (g)	Emergence count (%)	Grain yield (kg/ha)	Oil content (%)	Protein content (%)	Dry matter content (%)	Ash content (%)
Peredovik	19.5^{b}	169.10^{a}	98.00^{a}	62.25^{b}	29.88^{a}	68.90^{cd}	91.25^{a}	663.00^{abcd}	21.20^{a}	24.00^{c}	6.70^{c}	95.97^{a}
Cakinskij 268	16.13^{bc}	157.87^{abcd}	79.00^{e}	60.00^{c}	20.75^{cd}	61.70^{d}	90.31^{a}	574.60^{cd}	27.9^{e}	23.40^{d}	5.37^{f}	95.36^{bc}
Isaanka	24.00^{a}	132.10^{cd}	86.50^{d}	66.00^{a}	26.75^{ab}	89.04^{a}	95.44^{a}	735.83^{b}	29.20^{d}	25.00^{b}	5.52^{e}	96.07^{a}
Saturn	20.50^{ab}	120.10^{d}	97.63^{a}	59.57^{c}	18.25^{d}	84.00^{ab}	92.56^{a}	720.92^{ab}	28.30^{e}	26.15^{a}	6.62^{c}	95.02^{cd}
Funtua	20.00^{ab}	149.10^{abc}	94.63^{b}	57.63^{d}	28.88^{a}	68.90^{cd}	92.25^{a}	690.37^{abc}	32.06^{c}	25.20^{b}	7.59^{b}	96.14^{a}
Vniimk 8883	18.00^{bc}	138.80^{bcd}	94.88^{b}	60.00^{c}	25.75^{abc}	64.60^{cd}	90.50^{a}	590.42^{bcd}	36.20^{a}	26.40^{a}	7.32^{b}	92.83^{e}
Chernianka 66	13.13^{bc}	121.90^{d}	86.00^{b}	63.00^{b}	20.88^{d}	68.90^{bc}	92.25^{a}	659.08^{abcd}	132.80^{b}	22.31^{e}	5.62^{e}	95.52^{b}
Smena	24.13^{a}	162.62^{a}	86.00^{b}	67.13^{a}	30.13^{a}	92.60^{a}	93.50^{a}	749.08^{a}	28.25^{e}	25.20^{b}	5.96^{d}	94.85^{d}
Record	14.67^{c}	138.00^{bcd}	91.13^{c}	56.00^{e}	32.13^{bcd}	60.70^{d}	89.50^{a}	533.75^{d}	22.00^{f}	23.20^{d}	5.22^{f}	91.11^{f}

Means followed by the same letter(s) are significantly the same at the 5% level of probability (DMRT).

the trend was similar, i.e. Smena and Record turned out to be the highest and lowest yielders, respectively. In all three years, the standard error associated with grain yield was the highest since it is relative to the values obtained.

The earliest maturing variety in 1992 was Cakinskii 268 (74 days), whereas Vniimk 8883 matured late (101 days). In 1993 Cakinskij 268 and Chernianka 66 matured earlier (84 days) than the rest of the varieties. The variety Saturn had the longest number of days to maturity (99.00) in 1993. However, the two year data showed Cakinskij 268 (79 days) as an early maturing variety and Peredovik as a late maturing variety (98 days). Also, the variety Peredovik, took longer days to mature than the rest of the varieties. With respect to the other characters, various erratic trends were observed for each year and the combined years for the different varieties studied.

Using the Duncan's new multiple range test procedure (DNMRT), the treatment means were compared (Table 9). For capitulum diameter, the differences between the mean of variety Isaanka and Smena was not statistically significant. However, Peredovik had a mean value whose difference when compared to the mean of Record was statistically significant. Differences among mean values for all the nine treatments with respect to emergence count was statistically insignificant. The mean grain yield between Smena and Record was also found to be statistically significant, whereas the difference in mean yield between Peredovik and Chernianka 66 was statistically insignificant.

Genotypic variability

The ANOVA for the individual years and the two years combined for the different characters are shown in tables 10, 11 and 12 respectively. In 1992 and 1993, differences among genotypic mean squares with regards to all traits measured were statistically significant. The mean squares for the interaction of genotype x year was also found to be statistically significant for all traits measured except for protein, dry matter and ash contents. In general, the mean squares for the genotypes were higher than the genotype x year interaction values.

Table 10: Analysis of variance for different characters of nine sunflower varieties grown at Samaru (1992)

Source	df	Mean squares											
		Capitulum diameter	Plant height	Days to 50% flowering	Days to maturity	Number of leaves per plant	1000 grain weight	Emergence count	Grain yield	Oil content	Protein content	Dry matter content	Ash content
Replications	3												
Genotypes	8	40.74**	953.40**	257.34**	71.74**	44.69**	506.6**	64.30**	37102.00**	139.47**	17.47**	10.37**	2.46**
Errors	24	13.32	547.70	1.581	2.35	26.85	118.1	16.50	14491.00	0.39	0.11	0.22	0.11

* = Significant at 0.05% level of probability.
** = Significant at 0.01% level of probability.

Table 11: Analysis of variance for different characters of nine sunflower varieties grown at Samaru (1993)

Source	df	Mean squares											
		Capitulum diameter	Plant height	Days to 50% flowering	Days to maturity	Number of leaves per plant	1000 grain weight	Emergence count	Grain yield	Oil content	Protein content	Dry matter content	Ash content
Replications	3												
Genotypes	8	100.00**	2176.80**	136.75**	63.86**	147.25**	851.20**	23.7**	26577.00**	86.39**	4.04**	13.95**	4.50**
Errors	24	19.47	459.00	4.92	2.30	30.33	120.70	2.50	17839.00	0.17	0.13	0.02	0.03

* = Significant at 0.05% level of probability.
** = Significant at 0.01% level of probability.

Table 12: Combined analysis of variance for different characters of nine sunflower varieties grown in Samaru

Source	df	Mean Squares											
		Capitulum diameter	Plant height	Days to 50% flowering	Days to maturity	Number of leaves per plant	1000 grain weight	Emergence count	Grain yield	Oil content	Protein content	Dry matter content	Ash content
Replications	3												
Replications within years													
Years	1	3.56	128.00	0.00	2.72	238.35	13.70	18.00	25070.00	3.51	5.84	0.17	4.30
Genotypes	8	90.99**	2110.30**	107.19**	310.31**	157.28**	1140.90**	73.40**	46515.00**	186.74**	15.36**	23.14**	6.15*
Genotype x year	8	49.73**	1019.90**	28.41**	83.79**	34.66**	216.90**	14.60**	17304.00**	39.12*	0.15	1.18	0.81
Errors	48	16.00	479.80	2.21	3.33	27.77	133.10	7.20	15903.00	0.27	0.12	0.12	0.70

* = Significant at 0.05% level of probability.
** = Significant at 0.01% level of probability.

Estimates of genetic variance components

The components of genetic variance were computed from the results of the analysis of variance. Table 13 shows the estimates of genotypic variance, genotype x year interaction variance, phenotypic variance and error variance. In all cases, the standard errors were less than the estimates for phenotypic and error variances. For the genotypic variance estimates, the only exception was with capitulum diameter where the standard error exceeded the estimate. Similarly, number of leaves per plant had a standard error that surpassed its interaction (gxy) variance estimate. The phenotypic, genotypic and error variance estimates were relatively remarkable for plant height, 1000 grain weight and grain yield, whereas the genotype x year interaction variance estimates were pronounced for plant height and grain yield. The genotypic variance estimates for ash and dry matter content were very close to that of the phenotypic variance. However, the disparity between the genotypic and phenotypic variance estimates for capitulum diameter, plant height, days to maturity, days to 50% flowering, number of leaves per plant, 1000 grain weight, emergence count, grain yield, oil content and protein were quite noticeable.

Table 13: Estimates of phenotypic variance (σ^2_{ph}), genotypic variance (σ^2_g), genotype x environment interaction variance (σ^2_{gy}) and environmental variance (σ^2_e) with their respective standard errors of sunflower grown for two years at Samaru.

Character	$\sigma^2_{ph} \pm SE$	$\sigma^2_g \pm SE$	$\sigma^2_{gy} \pm SE$	$\sigma^2_e \pm SE$
Capitulum diameter	29.60 ± 5.09	5.16 ± 5.80	8.44 ± 5.62	16.00 ± 3.11
Plant height	751.13 ± 118.00	136.30 ± 131.02	135.03 ± 116.38	479.80 ± 93.20
Days to maturity	41.77 ± 17.35	28.32 ± 17.97	10.12 ± 9.37	3.33 ± 0.65
Days to 50% flowering	18.61 ± 5.99	9.85 ± 6.20	6.55 ± 3.18	2.21 ± 0.43
Number of leaves per plant	44.82 ± 8.79	15.33 ± 9.00	1.72 ± 4.10	27.77 ± 5.39
1000 grain weight	269.55 ± 63.78	115.50 ± 64.92	20.95 ± 25.10	133.10 ± 25.86
Emergence count (%)	137.70 ± 4.10	7.35 ± 4.18	-23.15 ± 5.46	107.20 ± 20.82
Grain yield	19887.13 ± 2592.00	3633.88 ± 2767.03	350.25 ± 2083.11	15903.00 ± 3089.27
Oil content	28.43 ± 10.44	18.45 ± 10.67	9.71 ± 4.37	0.27 ± 0.05
Protein content	2.78 ± 0.86	1.15 ± 0.92	1.51 ± 0.69	0.12 ± 0.02
Dry matter content	3.13 ± 1.29	2.74 ± 1.30	0.27 ± 0.13	0.12 ± 0.02
Ash content	0.92 ± 0.34	0.67 ± 0.35	0.18 ± 0.01	0.07 ± 0.01

Estimates of genotypic coefficient of variation, heritability, expected genetic advance and genetic advance in percent of mean

The estimates of genotypic coefficient of variation, expected genetic advance, expected genetic advance in percent of mean and broadsense heritability with their standard errors for the various traits are presented in table 14. The results showed that characters such as capitulum diameter, plant height, number of leaves per plant, 1000 grain weight and grain yield with fairly high phenotypic coefficient of variation (Table 5), also had high genotypic coefficient of variability. Most characters with fairly high phenotypic coefficients of variation also had high genotypic coefficients of variability. As the data for individual plants were available, the broad sense heritability estimates were computed on per plant basis rather than on per plot. All the heritability estimates were high except for capitulum diameter. The broad sense heritability estimates obtained ranged from 45.38% to 94.81% for capitulum diameter and dry matter content respectively. The standard error for all the characters studied were lower than the heritability estimates. The expected genetic advance ranged from 0.95 to 126.67. The results indicate that high heritability estimates are not necessarily associated with high expected genetic advance estimates. The expected genetic advance in percent of mean ranged from 2.37 to 45.72 . Dry matter content had the lowest and ash content had the highest. The traits which had high heritability as well as high genetic advance in percent of mean were ash content, number of leaves per plant and 1000 grain weight, whereas grain yield and oil content had moderate estimates. The trait with highest genetic advance was grain yield (126.67kg) while protein content had the least. (0.95).

Table 14: Estimates of genetic coefficient of variability (GVC) in percent, broad sense heritability (h^2) with standard error (±), expected genetic advance (ΔG) and expected genetic advance in percent of mean of sunflower grown for two years at Samaru.

Character	GVC	$h^2 \pm SE$	ΔG	ΔG in percent of mean
Capitulum diameter	51.81	0.4538 ± 0.5101	2.92	15.19
Plant height	98.00	0.5167 ± 0.4967	17.96	12.66
Days to maturity	40.10	0.7301 ± 0.4640	5.75	6.32
Days to 50% flowering	55.80	0.7351 ± 0.4627	3.67	5.99
Number of leaves per plant	78.60	0.7799 ± 0.4578	7.17	28.90
1000 grain weight	124.93	0.8099 ± 0.4552	17.88	23.16
Emergence count (%)	28.34	0.8007 ± 0.4553	12.01	13.12
Grain yield	235.18	0.6269 ± 0.4773	126.67	18.67
Oil content	80.23	0.7905 ± 0.4572	4.79	16.72
Protein content	20.03	0.5990 ± 0.4792	0.95	3.86
Dry matter content	17.01	0.9481 ± 0.4498	2.24	2.37
Ash content	32.85	0.8701 ± 0.4805	2.84	45.72

Correlations

Correlation coefficient values were computed from the analyses of variance and covariance. All possible correlation coefficients were computed from the means. The genotypic correlation coefficients are presented in tables 15, 16 and 17, for 1992, 1993 and 1992/93 combined, respectively. In the first year, a sizeable proportion of the correlation coefficients between different characters at both genotypic and phenotypic levels indicate highly significant relationships.

The correlations between emergence count and characters such as days to 50% flowering, capitulum diameter, 1000 grain weight, protein content, dry matter content and grain yield were positive and significant at phenotypic level. However, at genotypic levels, emergence count was negatively and significantly correlated with days to 50% flowering, days to maturity, plant height, oil content, dry matter content and grain yield. Capitulum diameter, 1000 grain weight and protein content were positively and significantly correlated to emergence count genotypically. Significant positive correlations at the genotypic levels were also observed between days to 50% flowering with plant height (r=0.38), capitulum diameter (r=0.96), number of leaves per plant (r=0.64), 1000 grain weight (r=0.50), dry matter (r=0.42) and grain yield (r=0.47). However, the phenotypic correlations between days to 50% flowering and the remaining traits computed were all not significant. Similarly ash content and grain yield were phenotypically and genotypically (r=0.18), (r=0.27) not significantly correlated.

Table 15: Phenotypic and genotypic correlations between different pairs of character in sunflower (1992)

Character	Emergence count (%)	Days to 50% flowering	Days to maturity	Plant height (cm)	Capitulum diameter (cm)	No. of leaves per plant	1000 grain weight (g)	Oil content (%)	Protein content (%)	Dry matter content (%)	Ash content (%)	Grain yield (kg/ha)
Emergence count (%)		0.57 -0.66	0.01 -0.03	0.06 -0.03	0.67** 0.96**	0.06 0.21	0.70** 0.93**	0.16 -0.21	0.38* 0.46*	0.95** -0.98**	0.18 0.16	0.74** 0.98**
Days to 50% flowering			0.01 0.03	0.09 0.38*	0.23 0.92**	0.13 0.64**	0.14 0.50**	0.08 0.25	0.06 0.20	0.03 0.42*	-0.07 -0.22	0.13 0.47**
Days to maturity				-0.30 -0.46	0.04 0.04	0.59* 0.64**	0.06 0.07	0.19 0.19	0.57** 0.58**	-0.07 -0.07	0.73** 0.75**	0.34 0.40*
Plant height (cm)					0.38 0.67**	0.24 0.60**	0.19 0.53**	-0.59** -0.90**	0.08 0.10	0.28 0.46*	-0.35 -0.55**	0.34 -0.52**
Capitulum diameter (cm)						0.11 0.44*	0.54** 0.98**	-0.63** -0.24	0.22 0.27	0.53** 0.64**	-0.25 -0.29	0.51** 0.60**
No. of leaves per plant		0.22 0.45*	-0.16 -0.15	0.14 0.22	0.20 0.36			0.06 0.09	0.36** 0.61**			
1000 grain weight (g)			-0.13 -0.15	0.26 0.30	0.55** 0.64**			-0.12 -0.17	0.14 0.16			
Oil content (%)				-0.17 -0.17	-0.14 -0.15			0.40* 0.39*	0.14 0.16			
Protein content (%)					0.18 0.73			0.70 0.72	0.20 0.23			
Dry matter content (%)								0.06 0.07	0.68 0.80			
Ash content (%)									0.18			

Upper and lower values represent phenotypic and genotypic correlation coefficients respectively.

* = Significant at 0.05% level of probability.
** = Significant at 0.01% level of probability.

In the subsequent year, 1993, the correlation coefficients were to a large extent indicating significant associations between the various traits. Days to 50% flowering was highly and positively correlated with 1000 grain weight, dry matter content, and grain yield at both phenotypic and genotypic levels. However, the correlations between days to 50% flowering and protein content (r=-0.69) was highly significant although negative at the genotypic level. Other characters like days to maturity, plant height and ash content were not significantly correlated to days to 50% flowering at both levels. Also days to maturity with plant height, and ash content were positively and significantly correlated. Negative but significant phenotypic and genotypic correlation were observed between days to maturity and oil content. Plant height was highly positively correlated with number of leaves per plant and ash content. However, its phenotypic and genotypic correlations with 1000 grain weight were negative although significant. Correlations between plant height with other characters like capitulum diameter, oil content, protein content, dry matter content and grain yield were not significant. All the correlations observed between capitulum diameter and other characters like number of leaves per plant, 1000 grain weight, oil content, protein content, ash content and grain yield were positive and significant at both genotypic and phenotypic levels. The only non-significant association arose between it and dry matter content. Number of leaves per plant was not significantly correlated with other traits tested at both levels with the exception of ash

content and grain yield, where the associations were highly significant. Although the correlation between 1000 grain weight and oil content was not significant at the phenotypic level, it was however highly significant at the genotypic level. Also, ash content and grain yield were not significantly correlated at both levels.

Table 16: Phenotypic and genotypic correlations between different pairs of character in sunflower (1993)

Character	Emergence count (%)	Days to 50% flowering	Days to maturity	Plant height (cm)	Capitulum diameter (cm)	No. of leaves per plant	1000 grain weight (g)	Oil content (%)	Protein content (%)	Dry matter content (%)	Ash content (%)	Grain yield (kg/ha)
Emergence count (%)		0.50** 0.23	-0.01 0.02	0.28 -0.12	0.59** -0.46*	0.33 -0.25	0.63** -0.42*	0.57** -0.29	0.07 0.02	0.42 -0.22	0.35 -0.20	0.56** 0.34
Days to 50% flowering			0.06 0.08	-0.05 -0.02	0.38* 0.43*	0.42* 0.48*	0.77** 0.86**	0.02).02	-0.16 -0.69**	0.49** 0.50**	-0.22 -0.22	0.79** 0.98**
Days to maturity				0.39* 0.49**	0.30 0.35	0.24 0.29	-0.11 -0.12	-0.41* -0.42*	0.32 0.32	-0.12 -0.11	0.47** 0.47**	0.37 0.37
Plant height (cm)					0.19 0.23	0.62** 0.98**	-0.50** -0.66**	-0.04 -0.05	0.03 0.05	0.11 0.12	0.50** 0.56**	0.05 -0.01
Capitulum diameter (cm)						0.70** 0.87**	0.51** 0.64**	0.47** 0.52**	0.39** 0.45**	0.28 0.31	0.48** 0.52**	0.81** 0.98**
No. of leaves per plant		0.21 0.21	0.22 0.24	-0.04 0.28	0.19 0.21	0.47** 0.54**	0.57** 0.83**					
1000 grain weight (g)			0.21 0.91	0.17 0.19	0.21 0.22	0.19 0.21	0.82** 0.97**					
Oil content (%)				-0.43 -0.44	0.41 0.41	0.48** 0.49**	0.16 0.26					
Protein content (%)					-0.110 -0.10	0.89** 0.53	0.16 0.19					
Dry matter content (%)						0.27 0.27	0.32 0.52**					
Ash content (%)							-0.01 -0.02					

Upper and lower values represent phenotypic and genotypic correlation coefficients respectively.

* = Significant at 0.05% level of probability.
** = Significant at 0.01% level of probability.

Table 17: Phenotypic and genotypic correlations between different pairs of character in sunflower (1992/93)

Character	Emergence count (%)	Days to 50% flowering	Days to maturity	Plant height (cm)	Capitulum diameter (cm)	No. of leaves per plant	1000 grain weight (g)	Oil content (%)	Protein content (%)	Dry matter content (%)	Ash content (%)	Grain yield (kg/ha)
Emergence count (%)		0.75** 0.98**	0.06 0.13	-0.17 -0.31	0.82** 0.60**	0.31* 0.46**	0.85** 0.70**	0.37** 0.43**	0.36** 0.40**	0.78** 0.77**	0.22 0.06	0.95** 0.98**
Days to 50% flowering			-0.20 -0.54**	0.01 0.15	0.72** 0.98**	0.39** 0.40**	0.80** 0.98**	0.10 0.03	0.06 0.02	0.50** 0.56**	0.24 0.10	0.25 0.93**
Days to maturity				0.01 0.09	0.23 0.40**	0.32* 0.38**	0.08 0.22	-0.12 -0.26	0.57** 0.70**	-0.11 -0.16	0.72** 0.34**	0.25 0.20
Plant height (cm)					0.03 -0.64**	0.62** 0.86**	0.34* 0.81**	-0.43** -0.77**	0.11 0.30	0.18 0.21	0.16 0.02	-0.17 -0.16
Capitulum diameter (cm)						0.56** 0.63**	0.86** 0.98**	0.09 0.06	0.58** 0.71**	0.51** 0.85**	0.21 0.06	0.89* 0.98*
No. of leaves per plant							0.21 0.20	-0.06 -0.25	0.24 0.08	0.26 0.35	0.40 0.16	0.37** 0.29**
1000 grain weight (g)								0.11 0.22	0.35* 0.58**	0.44** 0.56**	-0.10 -0.08	0.98** 0.98**
Oil content (%)									-0.38** -0.65**	0.13 0.15	0.40** 0.13	0.98** 0.15
Protein content (%)										0.01 0.08	0.68** 0.32*	0.40** 0.39**
Dry matter content (%)											0.18 0.08	0.69** 0.78**
Ash content (%)												0.21 0.16

Upper and lower values represent phenotypic and genotypic correlation coefficients respectively

* = significant at 0.05% level of probability
** = significant at 0.01% level of probability

The correlations of the various characters from the combined analysis are similar to those of 1992 and 1993. However most of the genotypic correlations were high. Days to 50% flowering was positively and significantly associated with capitulum diameter, number of leaves per plant, 1000 grain weight and dry matter content at phenotypic and genotypic levels. Genotypically, days to maturity and capitulum diameter are highly significantly correlated. Nevertheless, a phenotypically not significant correlation was observed between them on the other hand. Also the correlations between days to maturity and number of leaves per plant, protein content and ash content were genotypically and phenotypically significant. However, a negative and not significant association existed between days to maturity with oil content, and dry matter content at both levels. Plant height was consistently associated with number of leaves per plant at the genotypic level and the association was positive and significant. However, the association at the phenotypic level was not consistent. The correlations of plant height with oil content had also been consistently negative at both levels. Capitulum diameter was also phenotypically and genotypically correlated with number of leaves per plant, 1000 grain weight, protein content, dry matter content and grain yield and the correlations were positive and significant at both levels. However, the associations between number of leaves per plant and other characters like 1000 grain weight, oil content and protein were not significant. A significant association at both levels was, however, obtained between number of leaves per plant and grain yield. Also 1000 grain

weight was not significantly correlated with protein content, dry matter content and grain yield. A consistent negative correlation was observed between oil content and protein content. Ash content and grain yield were not significantly correlated at both phenotypic and genotypic levels.

CHAPTER V

DISCUSSIONS

Since each phenotype is the result of an interaction between the genotype and the environment, it is necessary to define within the model the major yield forming characters and the major environmental characters that affect them. When breeding for yield, those components which are morphologically identifiable at different stages of ontogenesis and which are in correlation with yield should be used in order to breed simultaneously for these characters and yield (Borojevic, 1981). Characters studied under the present investigation have all revealed considerable variations, indicating the possibility of yield improvement through appropriate breeding procedures. The phenotypic means of the different varieties also manifested a wide range of variation for the different traits measured (Tables 5, 6 and 7). In general, the 1993 overall performance was better than that of the preceding year probably due to favourable weather factors. For example, the 1992 rains arrived late, coupled with the water-logged nature of the field. However, the year 1993 experienced timely commencement of rainfall in addition to favourable soil conditions that allowed good drainage.

The range in days taken to reach maturity was almost the same for the variety Funtua and Vniimk 8883 (94 days) and Smena and Record (91 days), as shown in Table 7. Similar results were reported by Ogunremi (1979) in other sunflower varieties. The wide range in variability in grain yield obtained indicated that appropriate selection could produce adapted varieties comparable to what is obtained elsewhere in terms of grain yield. Also the range of capitulum diameter falls within the values reported by

Vranceanu et al (1984) and Rana et al (1991). The mean number of days to maturity (90.97) obtained in this result showed that the varieties matured earlier in Samaru than at their places of origin. It was reported by Dedio (1985) that thirteen U.S.A. hybrids had a maturity range of 112-120 days at Manitoba, Canada, between 1981-1984.

The ANOVA of tables 10, 11 and 12 showed highly significant differences for most of the characters measured. In the first year, 1992, all the genotypic mean squares were significant. Similar observations were made in the subsequent year and when the data were combined over the two years. According to Vranceanu and Stoenescu (1985), open pollinated varieties of sunflower will be more useful than hybrids for the characters that had no significant mean squares. If however, any of the characters had significant mean squares, hybrid varieties would produce more extreme values than population varieties. Consequently, the genotypic mean squares obtained in this study for all the characters measured suggest that hybrid varieties would be more useful than open pollinated varieties. This suggestion tallies with that of Unrau and White (1944), that increase in seed yields of early hybrids over open-pollinated cultivars ranged as high as 60%.

Hybrid seed development requires improved population from which inbreds can be extracted. Although several methods are used to develop inbreds lines depending on such factors as the source population available and specific programme objectives, sib matings are especially useful when development or maintenance of lines with a high degree of self incompatibility is desired (Fick 1978).

The genotype x year interactions were also significant for all the characters measured except for protein content, dry matter content and ash content. The non-significant genotype x year mean squares suggest the stability of these characters among the varieties. The significant genotype x year interaction mean squares for capitulum diameter, plant height, days to 50% flowering, days to maturity, number of leaves per plant, 1000 grain weight, emergence count, grain yield, and oil content suggest the unstable nature of these characters among the varieties.

A large genetic diversity would reduce the yield fluctuations in a certain area because different genotypes react differently to the environmental variation. Also as the presence of genetic variability is of importance to plant breeders, genetic variances as well as phenotypic and environmental variances were computed to study the available variability in the population. From table 13, it could be seen that high phenotypic, genotypic and environmental variances exist for plant height, 1000 grain weight and grain yield, while the genotype x year interaction variance in majority of the cases were higher than their respective environmental variances. The result revealed that considerable genetic variability was available for improvement. As the genetic variance estimates for grain yield was high, so was its corresponding genotypic coefficient of variability, indicating that the range of genetic variability inherent in the trait was relatively high.

In crop improvement, only the genetic component of variation is important since only this component is transmitted to the next generation (Singh, 1990). Since genotypic coefficient of variability does not indicate the amount of variation that is heritable, heritability estimates were therefore used to determine the proportion of total variation.

that was genetic. From table 14, it could be seen that almost all the traits measured were of high broadsense heritability with the exception of capitulum diameter. Estimates of heritability are very important to plant breeders because this parameter often determines progress made from selection. Broadsense heritability is the ratio of total genetic variance to the phenotypic variance.

This result indicates that phenotypic selection for all the characters measured are reliable with exception of capitulum diameter. It also shows the minimal role of environmental factors in determining the phenotype. The phenotype was a reflection of the genotype to a large extent. High heritability estimates were not in all cases associated with high genetic advance in percent of mean e.g. dry matter. Closely related results were obtained by other workers for the character number of leaves (Luczkiewicz, 1973). From the result of this study, the traits which have high heritability estimates as well as high genetic advance and high genetic advance in percent of mean are grain yield, 1000 grain weight and ash content. This shows that grain yield per hectare as well as 1000 grain weight and ash content could be improved upon through selection for these characters. The other which showed low genetic advance, but high heritability e.g. days to maturity and oil content indicate that the expression of these traits was conditioned by non-additive genes. Also for characters with low heritability estimates e.g capitulum diameter, it will be more pertinent to use a selection method that gives as much information as possible about each selected material (e.g S_1 selection). In addition, significant improvement in yield and combining ability of populations could be achieved by S_1.

Recurrent selection appears to be one of the most promising methods to increase the frequency of desirable genotypes in a source population and thus enhance the chances of success in isolating superior inbred lines. Each cycle of recurrent selection requires selfing and evaluation of selected plants, and subsequent inter-crossing of the progenies of superior selfed plants to produce seed for the next cycle of selection.

Several of the methods of recurrent selection used for hybrid development and improvement of maize breeding population, appear applicable to sunflower. These include the comprehensive breeding system outlined by Eberhart et al (1967), reciprocal full sib selection using multiple - eared or multiple - headed populations proposed by Hallauer (1967 and 1973) and several modified forms of recurrent selection reviewed by Sprague (1966).

Robinson et al., (1951) stated that most characters of economic importance such as yield, are complex in inheritance and may involve several related characters and hence the degree of phenotypic and genotypic correlations of the characters is important. The coefficient of genetic correlations are a measure of the commonness of genes governing the determination of two characters. That is, if two characteristics have no genes in common, we would expect them to be uncorrelated (Mode and Robinson, 1959). To the plant breeder, the most important correlations are those between yield and other related traits. These correlations are not only of interest from a theoretical consideration of the quantitative inheritance of these characters, but of practical value as well, since selection usually involves the changing of two or more traits simultaneously. The selection for one character results in a progress for all positively correlated but in a regress to all

negatively correlated characters. For these reasons, the phenotypic and genotypic correlation coefficients were computed for all possible combinations (tables 15, 16 and 17).

In general, the results from this study indicate that genotypic correlations were higher than the phenotypic correlations with few exceptions. This is in agreement with the findings of Varshney and Singh (1977), Alba and Greco (1979), Giriraz et al., (1979), and Punia and Gill (1994). These findings may mean that although there was a strong inherent association between the various characters, the phenotypic expression of the correlation was lessened under the influence of the environment.

In 1992, days to 50% flowering was genotypically correlated with grain yield. The same trend was noticed in 1993 and in the results of the combined analysis. These correlations are in agreement with those reported by Putt (1943), and Skoric (1974). This means that selection for this character to improve yield could be effective. Similarly, days to maturity was phenotypically and genotypically correlated with characters such as number of leaves per plant, protein content and ash content. However, the trend was not consistent probably due to the interaction of genotype by year. Plant height and oil content were negatively but significantly correlated at both levels. The trend was the same for 1993 and when the data were combined. This implies that selection for increase in plant height would lead to a reduction in the amount of oil contained in the grains. As days to maturity showed no significant phenotypic correlations with grain yield in both 1992 and 1993, and when the data was combined, it became evident that developing early maturing varieties might not be accompanied with

appreciable increase in yield. Similarly ash content was insignificantly correlated with grain yield in both years and when data was combined over the years at phenotypic and genotypic levels. This means that ash content was entirely independent of grain yield and that it could be improved without any compromise in yield. Similar results were obtained by Natali and Shaikh (1970) and Fick et al., (1974).

In 1993, similar to trends of the preceding year were observed for most characters, although few exceptions were noticed. Number of leaves per plant was phenotypically and genotypically associated with grain yield. The same results were obtained in the data of the preceding year and when combined for both years. This implies that the more the number of leaves per plant the higher the yield. The physiological explanation for such a correlation is apparent since the more the number of leaves the more will be the photosynthetic apparatus and hence the more the amount of food stored in the seed and the higher the seed yield. Similar results were reported by Scherbak and Efremova (1966) who observed positive correlations between grain yield with leaf area per plant, photosynthetic activity and seed weight. Oil content was not at all correlated with grain yield. This observation was consistent for all the tables of correlations. Consequently, oil content could therefore be improved along with seed yield without any compromise. This result agrees with that obtained by Punia and Gill (1994), but contradicts the findings of Suzer and Atakisi (1993).

The 1992/93 combined data (table 17) gives a more reliable correlation between the various characters. Correlation studies revealed that, in general, majority of the characters are associated with grain yield. For example, grain yield was positively and

significantly correlated with emergence count capitulum diameter, number of leaves per plant, 1000 grain weight, protein content and dry matter content at both phenotypic and genotypic levels. The association of yield with capitulum diameter indicates that selection for wider or bigger heads could result in increased yield. However the significant but negative phenotypic and genotypic correlations between plant height and oil content indicates that shorter plants produced more oil. The absence of significant correlation between days to maturity and grain yield implies that yield could be improved with early, medium or late maturing varieties. The highly significant phenotypic and genotypic correlations between protein content and grain yield also implies that selection for increase protein leads to a corresponding increase in grain yield.

From the results obtained, it could be seen that there is an ample opportunity for improving grain yield through its components viz emergence count, capitulum diameter, number of leaves per plant, 1000 grain weight, protein content and dry matter content. Continuous selection for these traits will therefore indirectly increase yield since direct selection based on the phenotypic performance of yield is usually not effective, but that based on its components could be more effective (Waldia et al., 1980). The most correlated traits with grain yield from this study at both genotypic and phenotypic levels were emergence count, 1000 grain weight, capitulum diameter, and dry matter content. This result corroborates Pathak and Dixit's observations of 1984, that capitulum diameter was among the most correlated traits with grain yield.

CHAPTER VI

SUMMARY AND CONCLUSION

Nine open pollinating sunflower genotypes collected from different parts of the world were grown in a randomized complete block design with four replications at Samaru, Nigeria during the wet seasons of 1992 and 1993. Each plot consisted of four rows and the two inner rows formed the net plot. From the net plot, twelve quantitative traits were measured and analysed.

Variations observed within the traits were highly significant. The traits which indicated a high level of variability were number of leaves per plant, capitulum diameter, plant height and grain yield. From the 1992 trials, the variety Chernianka 66 was the highest grain yielder whereas Record gave the least. However Smena and Record gave the highest and lowest yields, respectively in 1993.

From the ANOVA done, the genotypic mean squares obtained in this study for all the characters measured suggest that the most appropriate breeding procedure for all the twelve characters is to go for hybrid production that could produce more extreme value, rather than open pollinated varieties. Heritability values for the major yield components (number of days to 50% flowering, days to maturity, number of leaves per plant, 1000 grain weight, emergence count, oil content, dry matter and ash contents) were higher than those for grain yield in this study, suggesting that selection for increased yield through selection of yield components may be effective.

Correlation studies have indicated that there is an ample opportunity for improving grain yield through its components viz emergence count, capitulum diameter, number of leaves

per plant, 1000 grain weight, protein content and dry matter content. Continuous selection for these traits will therefore lead to an increase in grain yield.

The relatively good output of oil and protein inherent in the crop could be exploited to make up the nutritional deficiencies of the teeming population, who cannot afford other expensive protein delicacies.

REFERENCES

Abdel-Gawad, A.A.; Saleh, S.A. Aghoub, M.A. and M.M. El-Gazzar (1987). Correlations study between leaf surface, head characteristics and yields of certain sunflower cultivars in Egypt Annals of Agric Sci. Ain Shams Univ. 32 (2): 1213-1227.

Ado, S.G. and B. Tanimu (1986). Results of preliminary investigations on sunflower cultivars at Samaru Nigeria. Helia Nr 9 pp 13-15.

Ado, S.G., Tanimu B., Echekwu, C.A. and S.O. Alabi (1987). Correlations and path analysis between yield and other characteristics in sunflower Nigerian Journal of Agronomy 3(1): 1-4.

Ahmad, Q, Rana, M.A. and S.U.H Siddiqui (1991). Sunflower seed yield as influenced by some agronomic and seed characters. Euphytica 56 (2): 137-142.

Alam, M.S., Hossain, M.N., Khair, A.B. and M.A. Khan (1988). Genetic parameters and relationships among some agronomic characters in sunflower Bangladesh Journal of Agric 12 (2): 89-93.

Alba, E. Benvenut., A., Tuberosa, R. and G.P. Vanozzi. (1979). A path coefficient analysis of some yield components in sunflower. Helia 2: 25-29.

Alba, E. and I. Greco (1979). An analysis of the association factors influencing seed yield in sunflower (Helianthus annuus L.) Sunflower newsletter 2 (13): 13-15.

Al-Jibouri, H.A.; Miller, P.A. and H.F. Robinson (1958). Genotypic and environmental variances and covariances in an upland Cotton Cross of Interspecific origin Agronomy Journal 50: 633-636.

Anaschenko (1974). The initial material for sunflower heterosis breeding P. 391-393. In Proc. 6th Int. Sunflower Conf. (Buchatest, Romania).

Andrich, G., Baroncelli, S., Fiorentini, R. and G. Vanozzi (1984). Variability in the content of oleic acids in inbred lines of sunflower Journal of edible oil industry Uljarstvo pp 22.

Andrich, G., Baroncelli., S., Fiorentini, R. and G. Vanozzi (1985). Variability in content of oleic and linoleic acids in inbred lines of sunflower (Helianthus annuus L.) Agrochimica 24: 276-280.

Anonymous (1966). Encyclopaedia Americana pp 376.

Anonymous (1982). Indian Farming Special issue on oilseeds 32 (8): 3-116.

A.O.A.C. (1975). Official method of analysis of the Association of Analytic Chemists. 12th Edition Washington D.C. pp 483.

Appelqvist, L.A. (1978). Relationships between use of fertilizers and production of lipid Sunflower newsletter 3 (3): 47.

Asawa, E. (1977). Selection indices in sunflower for yield and oil. Ind J. Agric. Sci. 47 (10): 505-551.

Basudeo, S., Sacham, J.N. and S. Daroga (1977). Variability and correlations in sunflower (Helianthus annuus L.) Patnagar J. Res. 2 (1): 27-30.

Bedov, S. and S.D. Skoric (1981). Possibilities in increasing protein content in sunflower J. Edible oil Industry. Godina No 25. p 24.

Bedov, S. (1982). Variability in protein and amino acid contents in different sunflower inbreds. Proc. 10th Int. sunf. Conf. surfers paradise p 218-221.

Bedov, S. (1985). A study of combining ability for oil and protein contents in seed of different sunflower inbreds Proc. 11th Int. Sunf. Conf. Mardel plata In. J. Edible Oil Industry pp 22-26.

Benson, L. (1959). Plant Classification Health and Company Massachussettes U.S.A. p. 296-300.

Borojevic, S. (1981). Formation of the model of high yielding Wheat varieties (Serbo-Croat Modern Agriculture No 6 pp 33-47.

Burns, R.E. (1970). Head size as an indicator of plot yields Agron. J. 62: 112-113.

Burton, G.W. (1952). Quantitative inheritance in grasses. Proc. of the Int. Grassland Cong. Vol I: 273-283. In: Johnson et al (1955). Agron J. 47: 314-318.

Burton, G.W. and E.W. Devane (1963). Estimating heritability in Tall Fescue (Festuca arundinacea) from Replicated Clonal Material Agron J. 45: 478-487.

Carter, J.F. (ed) (1978). Sunflower Science and Technology Agronomy Series No 19 Amer. Soc. Agron. pp 1-257.

Caylak, B. and S.H. Emiroglusit (1984). Correlations among some agronomic and technological characters in sunflower (Helianthus annuus L.) In: Plant Breeding Abstract 58 (1): 75.

Chandra S. and I.J. Anand (1977). Association of morphological and physiological characters with seed yield and grain filling in sunflower Crop Improvement 4 (2): 170-176.

Char, M. and S.K. Dasgupta (1977). Effects of levels of Nitrogen and row spacing on growth yield and oil content of sunflower (Helianthus annuus L.) Oilseeds Journal Vol 7, No 3 pp 60-63.

Chaudhary S.K. and I.J. Anand (1985). Influence of various characters on yield of sunflower Journal of Oilseeds Res. 2 (1): 78-85.

Chaudhary S.K. and I.J. Anand (1987). Genetic and morphological variability for quantitative characters on sunflower J. Oilseeds Res. 4 (1): 97-102.

Dedio, W. (1985). Release of sunflower lines and Registration of sunflower hybrids Oilcrops Newsletter 2: 8-9.

Diaz, C.H. Velazquez O., Lopez M.T. Garcia O and M.J. Gomzales (1986). Phenotypic Correlations and path coefficient for agronomic characters in sunflower Ciencias de la Agric 29: 55-58.

Dilruba B., Khan, M.S. and M.A. Khaleque (1988). Genetic and Environmental Variability in sunflower (Helianthus annuus L.) Bangladesh J. Agric. 13 (1): 11-15.

Djakov A.B. (1986). Related variability of trait complex in the course of sunflower selection (in Rusian)Selskohozjastvenaja biologija 1: 77-83.

Dua, R.P. and T.P. Yadava (1985). Genetics of seed yield and its components in sunflower. Proc. 11th Int. Sunf. Conf. Mardel Plata pp 627-632.

Earle, F.R.; Vanetlen, G.H., Clark, T.F. and I.A. Wolfe (1968). Compositional data on sunflower seed J. Amer. Oil Soc. 45: 878-879.

El-Baradi, T.A. (1973). Sunflower. Trop Abst. 27: 309-316.

Ennes, H., D.G. Dorrel., Hoes, J.A. and W.O. Chubb (1976). Sunflower Research: A Progress report. Proc. 4th Int. Sunf. Conf. Memphis Tenn. 4: 162-167.

Fehr W.R. (ed) (1987). Principles of cultivar Development Vol 2 Crop Species Macmillan Pub. Co. N.Y. pp 626-668.

Fernandez-Martinez, J. and E. Alba (1984). Breeding for oil and meal quality in sunflower Proc. Int Symp. Sci. and Biotech for an integral sunf. Utilization pp 75-97.

Fernandez-Martinez J., Dominiquez G.J. and J.A. Ramirez (1987) Obtention de das lineas puras de girasoi con al tos neveles de acido oleico. Producion begetal, 4: 7-24.

Fick, G.N. (1975). Heritability of oil contents in sunflower Crop Sci. 15: 77-78.

Fick, G.N. (1978). Breeding and Genetics Sunflower Science and Technology Agronomy No 19: 299-338.

Fick, G.N. (1984). Inheritance of High Oleic acids in the seed oil of sunflower In: Proc. Sunflower Research Workshop, Bismarck, No 9-10.

Fick, G.N., Zimmer, D.E. and D.C. Zimmerman (1974). Correlations of seed oil content in sunflower with other plant parts and seed characteristics Crop Sci. 14: 755-757.

Foti, S. and V. Abatte (1982). Analysis of yield variation and its components in sunflower (Helianthus annuus L.) grown in dry conditions Rivista di Agronomica 16 (2): 214-22.

Georgieva-Todorova, J. and A. Hristova, (1975). Studies on several wild growing Helianthus species. C.R. Acad. Agric. G. Dmitrov 8(4): 51-55 Sofia, Bulgaria.

Giriraz, K.; Vidyashankar T.S., Venkataram, M.N. and S. Seethran (1979). Path Coefficient analysis of seed yield in sunflower Sunflower newsletter 3(4): 10-12.

Gomzalez, G.J. and A.E. Angeles (1986). An early test of General Combining Ability in two varieties of sunflower (Helianthus annuus L.) Plant Breeding Abstract 56 (1):59.

Grundy, S.M. (1986). Comparison of mono-unsaturated fatty acids and carbohydrates for lowering plasma cholesterol N. Engl. J. Med. 314: 747-748.

Gundaev, I.A. (1971). Basic principles of sunflower selection P. 417-465. In: Sunflower Science and Technology, Agronomy 19, pp. 319.

Hallauer, A.R. and J.B. Miranda, F.O (1981). Quantitative Genetics in Maize Breeding Iowa State Univ. Press. Pp 150-153.

Hanson, C.H., Robinson, H.F. and R.E. Comostock (1956). Biometrical Studies of yield in segregating population of Korean Lespedez Agron. Journal 48: 268-272.

Harmati, I. (1990). Variety and Plant Density Trials with sunflower on slightly Calcareous Sand Between Danube and Tisza Rivers. Field Crops Abstract 11(43): 8346.

Ivanov, I.G. (1974) Variation of the protein, lysine and chlorogenic acid content in some sunflower selfed lines Rastenievud Nauk 12(9): 30-35.

Ivanov, P. (1974). Biochemical differentiation of sunflower varieties as a result of inbreeding. Proc. 6th Int. Sunf. Conf. Bucharest Romania pp 225-231.

Ivanov, P. and Y. Stoyanova (1980). Studies on the genotypic and phenotypic variability and some correlations in sunflower (Helianthus annuus L.) Proc. 9th Int. Sunf. Conf. Spain pp 336-342.

Johnson, W.H. Robinson H.F. and R.E. Comstock (1955a). Estimates of genetic and environmental variability in soyabeans Agron J. 47: 314-318.

Johnson, W.H. Robinson H.F. and R.E. Comstock (1955b). Genotypic and Phenotypic Correlations in soyabean and their implications in selection Agron J 47: 477-483

Kesteloot, J.A.; Heursel J. and F.M. Pauwels (1985). Estimation of heritability and genetic variation in sunflower (Helianthus annuss L.) Helia No 8 pp 9.

Khan, M.I. Raja, Z.I. and R. Muhammad (1989). Correlations study in sunflower (Helianthus annuus L.) J. Agric Res. Lahore Pakistan 27 (4): 275-279.

Khanna, K.R. (1972). Factors affecting the production of filled seeds in sunflower. Euphytica 21 (2): 384-387.

Kinnman, M.L. (1970). New developments in the USDA and state experimentation station sunflower breeding programmes. In Proc. 4th Int. Sunf. Conf. (Memphis, Tenn.) pp 167-172.

Kloczowki, Z. (1975). Studies on some features of oil sunflower and their significance in breeding that plant in Poland (In Polish) Hodowla Rosi Alim Nasienn 19 (2): 89-131.

Kovacik A. and V. Skaloud (1978). Contribution to defining the inheritance of earliness in sunflower and the method of exploitation in breeding Proc. 8th Int. Sunf. Conf. Minnesota U.S.A. pp 437-440.

Kovacik, A. and Skaloud (1979). Pre-requisites for the determination of sunflower ideotype for the Northern Regions. Rostlvyroba 25 (5): 551-556.

Kumar, R. (1976). Variability and Path Coefficient Studies in sunflower (Helianthus annuus L.) M.Sc. Thesis H.A.U. Hissar India.

Larshmanaiah, V.H. (1980). Genetic Variability and association of morpholical characters with seed yield and oil content in sunflower (Helianthus annuus L.) Mysore J. Agric. Sci. 14 (2): 259-262.

Leclerq, P. (1969). Une Sterilite cytoplasmique Chez le tournesol Ann. Amerlior Plant 19: 99-106.

Leclerq, P. (1971). La sterilite male cytoplasmique du tournesol. I. Premieres etudes surla restauration de la fertilite Ann Amedior Plant 21: 45-54.

Leclerq, P. (1982). Etude de divers cas de sterilite male cytoplasmique chez le turnesol Agronomie 3: 185-187.

Loubser, H.L. and C.L. Grimbeek (1983). The influence of fertilization on the oil concentration of sunflower seed and linoleic acid concentration of the oil. Proc. 15th Annual Conf. S. Africa. Soc. Crop Production. Pp 661-672.

Luczkiewicz T. (1973). The variability and heritability of a range of features both natural and induced by x-irradiation in sunflower. Zakoriczonych PAN 339-340.

Majid, H.R. and A.A. Schneiter (1987). Yield and Quality of Semi-dwarf and standard height sunflower hybrids grown at five locations Agronomy Journal 79: 681-684.

Marinescu, (1980). The relationships between oil and Protein in sunflower seeds, the accumulation of oil and protein in seeds and the significance of their relative values. Bulletin de J. Academie des sciences Agricoles et Forestieres 10: 37-41.

Marinkovic, R. (1982). Inheritance of plant height and leaf numbers in diallel crossing Proc 10th Int. Sunf. Conf. Surfers paradise Australia 232-233.

Marinkovic, R. (1992). Path Coefficient analysis of some yield components of sunflower Euphytica 60: 201-205.

Miller, B.G.; Oplinger E.S. R.; Peters, R. J. and G. Weis (1984). Effect of planting date and plant population on sunflower performance Agronomy Journal. 76: 511.

Miller, J.F. Zimmerman, D.C. and B.A. Vick (1987). Genetic control of high oleic acid content in sunflower Crop Sci 27: 923-926.

Misra, R.; Srivastava, A.N.; Chandra, D.R. and S. Singh (1985). Path analysis for yield components in sunflower Agric. Sci. Digest 5: 38-40.

Mode, C.J. and H.F. Robinson (1959). Pleiotropism and the genetic variance and covariances Biometics 15: 518-537.

Morozou, V.K. (1970). Sunflower selection for yield (in Rusian) Selekciya i semenovodstvo No 18 pp 25.

Natali, A.H. and J.M. Shaikh (1970). Correlations of seed yield and other characters in sunflower. Proc. 21st and 22nd Pakistani Sci. Conf. pp 1-25.

Niranjana, M. and K.G. Shanbulingap (1989). Path analysis for seed yield in sunflower J. Oilseeds Res. 6 (1): 22-25.

Obi, I.U. (1986). Statistical methods of detecting differences between treatment means SNAAP Press pp 13-17.

Ogunremi, E.A. (1979). Preliminary trials on sunflower performance in Southern Nigeria In: Vegetables for hot humid tropics No 4 pp 40-42.

Omran, A.C., Abbel-Zahab, A.A. and M.A. Haiki (1976). Evaluation of sunflower cultivars, heritability and variability of metric traits. Proc. 7th Int. Sunf. Conf. Krasnoda, USSR pp 20-36.

Omran, A.O. Magghed, A.A. and F.H. Nofa (1979). Effect of sowing dates on variability and correlations of mature sunflower characters. Agric Res. Review 57 (9): 75-85.

Pandey, S. and E.T. Gritton (1975). Genotypic and Phenotypic Variances and correlations in peas. Crop Sci 15: 353-356.

Pathak, R.S. (1974). Yield Components of sunflower Proc. 6th Int. Sunf. Conf. Bucharest Romania, 22-24 July, pp 271-281.

Pathak, A.R. Kukadia, M.U. and B.A. Kunadia (1987). Variability and correlation studies in sunflower Plant Breeding Abstract 57 (10): 958.

Pathak, K.C. and S.K. Dixit (1984). Components of seed yield in sunflower (Helianthus annuus L.) Ind J. Agron. 22 (2): 115-116.

Petakov, D. (1992). Oil content in different types of sunflower hybrids. Helia, 15 Nr. 16, pp. 29-34.

Picq, G. and P.A. Abramousky (1992). Growth indicators and conditions linked to oil and protein content and yield in sunflower (Helianthus annuus L.) achenes. Oliagnieux Corps grass No Revues Mensuere pp 35-38.

Piskov, A. (1983). Variation and heritability of oil content in the seeds in the primary seed production of the sunflower variety Peredovic Plant Breeding Abstract (7): 534.

Popova, E.V. (1978). Changes in Oil and Fatty acids content in germinating seeds of sunflower Sunflower newsletter 2(1): 32-36.

Potdar, M.V., Pawar K.R. and L. Sreenivas (1977). Simple correlation and regression studies between grain yield and yield attributing characters in sunflower Indian J. Agron 22 (2): 115-116.

Punia, M.S. and H.S. Gill (1994). Correlations and Path Coefficient analysis for seed yield traits in sunflower (Helianthus annuus L.) Helia 17 (20): 7-21.

Pustovoit, V.S. (1965). Conclusions of work on the selection and seed production of sunflower Agrobiology 5: 672-679.

Putt, E.D. (1943). Association of seed yield and oil content with other characters in sunflower Sci Agric 23: 377-383.

Putt, E.D. (1966). Heterosis, Combining ability and predicted synthetics from diallel cross in sunflower (Helianthus annuus L). Can J. Pl. Sci. 46: 1.

Putt, E.D. Graig,; B.M. and R.B. Carlson (1969). Variation in composition of sunflower oil from composite samples and single seeds of varieties and inbred lines. J. Amer. oil Chem Soc. 46: 126-129.

Putt, E.D. (1978). History and present World Status In: JF Carter (ed) Sunflower Science and Technology Agronomy 19:1-30.

Rana, M.A.; Ayubkahn, M., Yusuf M. and S.M. Mirza (1991). Evaulation of 26 sunflower CVs in Islamabad Helia 14 (14): 19-28.

Randall, E.L. (1974). Improve method for fat and oil analysis by a new process of extraction A.O.A.C. Journal 57 (5): 1165-1168.

Rincon, C. and Palafox (1986). Recurrent selection for G.C.A. in sunflower (Helianthus annuus L.) Plant Breeding Abstracts 56 (1): 60.

Rehm, S. and G. Espig (1991). The cultivated Plants of the tropics and subtropics, pp 102-103. CTA.

Roathe W.W., Hammond J.J., and J.F. Miller (1982). Genetic effects of days to flowering in sunflower (Helianthus annuus L.) under short-day regimes. Proc. 10th Int. Sunf. Conf. Australia. 247-249.

Robinson, R.G. (1975). Amino acid and elemental composition of sunflower and pumpkin seeds Agron. . 67: 541-544.

Robinson, H.F., Comstock, P.E. and P.H. Harvey (1951). Genotypic and Phenotypic correlations in corn and their implications in selection Agron J. 43: 282-289.

Robinson, R.G., J.H. Ford, Less Chem, W.E., Rabads D.L. Smith, L.J., Warnes D.D. and J.V. Wiersma (1980). Response of sunflower to plant population Agron J. 77:. 869-71.

Ross, A.M. (1939). Some morphological characters of sunflower (Helianthus annuus L.) in their relation to yield of seed and oil Sci. Agric 19: 372-379.

Russel, W.A. (1949). A study of the inter-relationships of seed yield, oil content and other agronomic characters with sunflower inbred lines and their top cross. Can. J. Agric Sci 3: 2.

Russel, W.A. A study of the inter-relationships of seed yield, oil content and other agronomic characters with sunflower inbred lines and top crosses Can. J. of Agric. Sci 33: 291-314.

Schneiter, A., Hussain, S.W. and B.L. Johnson (1992). Planting Date studies with Early Maturing Sunflower Hybrids Field Crop Abstract 2 (42): 1173.

Schuster, W. (1964). In Zucht and Heterosis bei der son nenblum Habilitation schrift In: J.Edible oil Industry pp 16.

Schuster, W. and I. Kubler (1983). Possibilities of increasing the genetic variability of sunflower due to seed quality composition Helia No 6 pp 5-12.

Shabana, R. (1974). Genetic variability of the yield components of oil in different sunflower varieties and inbred lines. Ph.D. Thesis Novisad Univ. Yugoslavia.

Shabana, R. (1974). Genetic variability of sunflower varieties and inbred lines Proc. 6th Int. Sunf. Conf. Bucharest, Romania pp 263-269.

Schherbak, S.N. and V.V. Efremova (1966). Photosynthetic force and productivity of some varieties of sunflower In: Sunflower Science and Technology ed J.F. Carter (1978). Agron 19 Inc. Publishers, Madison Wisconsin, USA. p 285-286.

Sheriff, N.M. Apparandurai, R. and Sreeranga -Samy (1987). Correlation and Path Coefficient analysis in sunflower Ind J. Agric Sci. 57 (2): 125-127.

Sidhu, B.S. and D.S. BAins (1980). Correlations between seed yield, yield attributing and quality characteristics of sunflower Ind J. Agron 25 (1): 156-157.

Singh, B.D. (1990). Plant Breeding Principles and method 4th edition Kalyani Publishers pp 95-97.

Sing, B., Sacham, J.N. Singh (1977). Variability and Correlation studies in sunflower Pantnagar J. Res. 2 (1): 27-31.

Singh, B. and D. Singh (1977). Variability and correlation studies in sunflower Pantnagar J. Res. 2 (1): 27-30.

Singh, S.B. and K.S. Labana (1990). Correlation and Path analysis in sunflower Crop Improvement 17 (1): 49-53.

Skoric D. (1974). Correlation among the most important characters of sunflower in F_1 generation. Proc. 6th Int. Sunf. Conf. 22-24 July Bucharest Romania pp 283-289.

Skoric, D. Vorosbaranyi, I., Cupina, T. and R. Marinkovic (1978). Inheritance of fatty acid composition in F_1 generation of sunflower. Proc. 8th Int. Sunf. Conf. Minnea Polis USA. pp 472-479.

Skoric, D., Bedov S. and K. Konstatinnov (1978). Studies of oil and protein contents and composition in genetically divergent sunflower genotypes. Proc. 8th Int. Sunf. Conf. Minneapolis. P 516-524.

Skoric, D. Vorosbaranyi I. and S. Bedov (1982). Variability in the composition of higher fatty acids in oil of sunflower inbreds wth different oil content in seed. Proc. 10th Int. Sunf. Conf. Surfers Paradise pp 215-218.

Soldatov, K.I. (1976). Chemical mutagenesis in sunflower breeding In: Int. Sunf. Conf. Krasnoda USSR pp 352.357.

Sosulski, F.W. and G. Sarwar (1973). Amino acid composition of oilseed meals and protein isolates. Can. Inst. Food Sci. Tech. J. 6(1): 1-5.

Stanojevic, D. (1989). Investigations of the effect of plant density on quantitative properties of domestic sunflower hybrids Field Crops Abstracts 42 (2): 117.

Stoyanova, V. and P. Ivanov (1975). Inheritance of oil and protein content in first hybrid progeny Rastenievud Sofia Bulgaria. Nauk 12 (19): 30-35.

Stoyanova, Y., Velkov, I. and I. Ivanov, (1978). Stanjei sunckoreta (ruski) Bulletin Vniimk Vipusk 2: 7-11.

Suzer, S. and I. Atakisi (1993). Yield component of sunflower hybrids of different height Helia 16 (18): 35-40.

Sychev, I.E. (1986). Variability and heritability of the plant interaction criterion in sunflower stand, at high density Plant Breeding Abstract 56 (2): 133.

Tanimu, B. and S.G. Ado (1988). Relationships between yield and yield components in forty population of sunflower Helia No 11 pp 17-20.

Tyagi, A.P. (1985). Association and path analysis of yield components and oil percentage in sunflower. Proc. 11th Int. Sunf. Conf. Mardel Planta, pp 807-812.

Urie, L. (1985). Inheritance of high oleic acid in sunflower Crop Sci 25: 986-989.

Vagvolgyi, S. (1989). Correlations between leaf area, chlorophyll content and yield of sunflower Novenyetermeles 38 (1): 37-43.

Vaniseree, G., Ananthasayana K., Nagablysshamana G.V.S. and G.A. Jagadish (1988). Correlation and path coefficient analysis in sunflower (Helianthus annuus L.) J. Oilseeds Res 2: 147-149.

Vanozzi, G.P. Belloni, P. and F. ed Martrorana (1986). Correlazione tra fattori productivi nel girasole (Helianthus annuus L.) Sementia Eletta 32: 25-31.

Varshney, S.K. and B. Singh (1977). Correlation and path coefficient analysis in sunflower (Helianthus annuus L.) Pantnagar J. Res. 2: 147-149.

Velkov, V.N. (1980). Relationships between seed yield and some characters in sunflower. Plant Breeding Abstracts 52 (6): 468.

Venturi, G., Abbate, V., Amoducci, M.T. Bonari E. Cremaschi D. Gambelli and E. Salera (1981). Sunflower cultivars in different Italian Environments. 4th Consultation F.A.O. on European Cooperation Network on Sunflower Pisa Rome pp 41-96.

Visic, M. (1991). Correlation between eight characters in three sunflower hybrids and path analysis coefficient Savremena poljoprivreda 39: 27-34.

Voskobolnik L.K. and I.V. Marin (1989). Correlations of the main yield components of sunflower lines Selektsiya (1): 16-18.

Vranceanu, A.V. (1974). Sunflower in Romania Hoarea-Soarelui pp 1-60.

Vranceanu, A.V. and F., Stoenescu (1971). Pollen Fertility restore. gene from cultivated sunflower (Helianthus annuus L.) Euphytica 20: 536-41.

Vranceanu, A.V. and F. Stoenescu (1985). Genetic Resemblance of sunflower cultivars tested in International trials Helia No 8 pp 9-16.

Vranceanu, A.V. Stoenescu F.M. and G. Soare (1984). Results of the 4th experimental cycle with sunflower cultivars biennial cycle. Helia 7: 5-15.

Vranceanu, A.V. Stonescu F.M. and G. Soare (1987). Trends in Sunflower breeding through Genetic Gain Helia No 10 pp 5-8.

Vranceanu, A.V. and N. Pirvu (1990). Genetic Advance realized in breeding sunflower in Romania Plant Breeding Abstracts 6 (1): 76.

Waldia, R.S. Lal, S. and K. Arora (1980). Association of grain yield and its components in advance generation of Urd Bean (Vigna mungo L Heppe) In: Tropical Grain Legume Bulletin 17/18: 35-37.

Wolfe, T.K. (1959). Production of Field Crops A textbook of Agron. 5th Ed. McGraw Hill pp 614-616.