CORRELATION BETWEEN SOME YIELD FACTORS IN SUNFLOWER (Helianthus annuus L.)

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SUMMARY

The Authors refer about the results of a three-years (1987, 1988, 1989) study on 10 Sunflower varieties applying the Path-coefficient method. In connection with the examinated characters (plant height, head diameter, days to flowering, etc.), the Path-coefficient analysis outlined the importance of the positive direct effect of some of these characters on seed yield.

INTRODUCTION

Sunflower (Helianthus annuus L.) is one of the most cultivated oleaginous crops in the world. Due to its high economical importance, a strong interest lies upon all the researches aimed to determine which yield factors, and to what extent, play some role in the productive behaviour of the plant. A first information may be obtained from the analysis of the correlation between the different characters under control. Such an analysis, however, gives useful information about their association level, but not about the effect that they have, directly or indirectly, which means through the influence upon other characters. If a precise cause-effect relation, "a *priori*" stated, exists, such an information may be obtained from the "path - coefficient" analysis (Wright, 1921; Dewey and Lu, 1959).

This is a standardized partial regression analysis, that allows to partition the correlation coefficient between two variables into one direct effect (unidirectional pathways, P), and many indirect effects through all the other examined variables (pathway P x correlation coefficient r).

This method, expecially useful for the large deal of informations that it may give to the breeders, has been widely applied to many crops, including Sunflower (Alba et al, 1979; Vannozzi et al., 1986).

This work has been carried out with the aim to give further informations about the associations among yields, most important bio-morphological traits and length of periods between the most important phenological stages, in Sunflower on dry conditions.

MATERIALS AND METHODS

The trial has been carried out in a three-years period (1987/89) into the experimental farm "Sparacia" (AG), located at an average altitude of 400 m above sea level, in a representative area of inner hilly clayey Sicilian environments.

Tab. 1 reports the most important pedological characters of soils used for the trial.

Temperature and rainfall in the trial period (February - August), showed in fig. 1 (a, b, c) have been characterized by a reduced rainfall amount in 1st and 3rd years (152 and 138 mm, respectively), even if in 1987 it had a more homogeneous distribution and summer temperatures were higher. In 1988 rainfall reached the amount of 218 mm, above all in February, March and April, very close to the sowing period.

In the trial, nine Sunflower varieties different as for cicle length and size were put in comparison. They were: Isa (early), Florom 305, Primasol and Romsun HS. 90 (medium-early), Gloriasol, Topflor and Romsun HS 52 (medium), Stromboli and Vulcano (late). Every year the soil was tilled in Summer, ploughing to 30 - 35 cm, and at the same time it was fertilized with 100 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1}; in one amount, at sowing time, 150 kg N ha^{-1} in ureic form were distributed. Before Sunflower, Barley was always cultivated.

The randomized block design with three repetitions was used; plot area was 36 m^2 (6 x 6 m), with a 60 cm distance between rows; the productive, biometrical and phenological data were collected from the four central rows.

Sunflower was sowed on March 7th 1987, 11th 1988 and 7th 1989, by hand-distribution of seeds; furtherly, at the growth stage of 2-3 couples of leaves, plant density was thinned out to 5 plants m^{-2}.

Weed control was obtained only with harrowings; in order to avoid damages from birds, every head was covered with a small mesh-sack.

Harvesting was always hand-made, in the 2nd and 3rd ten days of August, in relation with ripening degree of varieties.

The following data were collected: seeds yield, oil content of seeds, weight of 1000 seeds, plant height, average head and barren part diameter, dates of most important growth stages (emergence, appearance of flower bud, flowering and ripening).

With the aim to state the association level between yield, oil content and all the other characters, the phenotypic correlations were estimated for all the combinations of characters; moreover, the "path-coefficients" analysis was carried out through the simultaneous resolution of the equations system as described by Dewey and Lu (1959).

RESULTS

Correlations

Yield components vs seeds yield and oil content

1987

Correlation analysis (tab. 2) showed a good positive correlation between yield and weight of 1000 seeds (r= 0.698) and a negative one between the first and the sterility of head (r= -0.617). Although positive, negligible was the correlation between seeds yield and head diameter. None of the observed biometrical traits showed a significant correlation with the oil content of seeds.

Both plant height and head barren area showed a negative correlation with the weight of 1000 seeds. The results also showed a hardly explainable significant association between plant height and head sterility, maybe due to the extreme vegetative vigour of some individuals, maybe associated with a reduction of productive performances.

1988

In the second year (tab. 3) positive correlations were observed between yield and weight of 1000 seeds (r= 0.588) and head diameter, while negatively correlated the former was with plant height and, above all, with head sterility (r= -0.662).

The oil content of seeds showed negative associations with the weight of 1000 seeds (r= -0.428) and with head sterility (r= -0.314), while it was positively associated with plant height (r= 0.507).

Also in 1988 both plant height and head sterility were negatively correlated with the weight of 1000 seeds.

1989

The positive relationship (tab. 4) between weight of 1000 seeds and yield (r= 0.672), and the negative one between seeds yield and head sterility (r= -0.738) were confirmed. In the same way, the inverse correlation between weight of 1000 seeds and head sterility (r= -0.645) was also confirmed.

Seeds oil percentage was significantly and positively correlated only with head barren area and with plant heigth (r= 0.449 and r= 0.532, respectively).

Growth stages vs. seeds yield and oil content

Correlation coefficients between the lenght of periods between the different plant growth stages (emergence, appearance of flower bud, flowering and physiological ripening) and yield, reported in tabs. 5, 6 and 7, show how, in all the three trial years, the last character was significantly and positively correlated with the length of all the examined phases, expecially those included from flower bud to ripening.

Oil content of seeds in the first year was not significantly correlated with growth stages lenght, while in the second and third years the highest "r" values were those with the periods emergence - flower bud, flower bud - flowering and flowering - ripening.

Among the phases, the highest correlation coefficients have always been those between emergence - flower bud and flower bud - flowering (r= 0.843, r= 0.784 and r= 0.843, respectively for the three years).

Path analysis

Yield components vs. seeds yield

1987

The correlation coefficient between weight of 1000 seeds and yield (r= 0.698) resulted to be composed (fig. 2 and tab. 8) by a direct positive effect (0.704) and by remarkable indirect effects, negative through plant height (-0.226) and positive through head sterility (0.268). Those indirect effects, having opposite signes, do not seem to modify the direct effect on seeds yield.

Head sterility and seeds yield showed a remarkable inverse correlation (r= -0.617), composed by a strong direct effect (-0.421) and by an indirect one via weight of 1000 seeds, partially balanced by an indirect effect through plant height (0.271). The correlation coefficient between plant height and seeds yield, very low, results to be composed by a more important positive direct effect (0.487) and by cospicuous negative indirect effects via weight of 1000 seeds (-0.327) and head sterility (-0.238), pointing out, at the end, that the final yield result is (under certain pedo-climatical conditions) also stated by the result of the competition between the development of vegetative and reproductive parts of plant.

1988

The examination of fig. 3 and tab. 8 shows that the weight of 1000 seeds exerted on seeds yield a strong direct effect (0.413). This was lower than the one expressed by the correlation coefficient (r= 0.589), due to the presence of an indirect positive influence via head sterility, with which the weight of 1000 seeds was negatively correlated (r= -0.551) and that shows a direct negative effect (-0.311) on seeds yield.

Also the direct effect of head sterility (-0.311) seemed to reduce the direct effect of this character on the productive behaviour of the plant, as was showed, instead, by the correlation coefficient (r= -0.662). This is due, as it seems, to the indirect negative effect also exerted via the weight of 1000 seeds (-0.228).

The so analyzed cause-effect system, however, seems to ascribe to the examined characters approximately only one half of the responsability in determining the yield result (Rx= 0.508).

1989

The analysis of data collected in the third year of trial (fig. 4 and tab. 8) seems to confirm the direct influence on seeds yield of the weight of seeds (P= 0.551) and of head diameter. The first character, however, showed a path coefficient with seeds yield much lower than the correlation coefficient, because of the indirect positive effect exerted via head sterility (0.205), which is directly correlated with seeds yield.

Head diameter showed a positive direct effect on seeds yield (0.385) and a negative indirect one via weight of 1000 seeds (0.133).

Head sterility, that showed a close and inverse correlation with seeds yield (r= -0.738), put in evidence a lower direct association (-0.318) because of the strong indirect negative effect exerted via weight of 1000 seeds (-0.355), that is, on the contrary, closely associated with the production.

Yield components vs. oil content

1987

Because of the very low significance of the correlation coefficients observed on data collected in 1987, calculation of path coefficient has not been estimated.

1988

Oil content in seeds was directly influenced by plant height (0.452), that confirmed the value of correlation coefficient (fig. 5). The weight of 1000 seeds, on the contrary, seemed to have on it a negative direct effect (-0.166) lower than the one showed by the correlation coefficient, that was probably due to the negative indirect effect via plant height (-0.259), with which it was negatively correlated (r= -0.475) (tab. 9).

1989

The path analysis confirmed the relatively important role of plant height in determining the oil content of seeds. The weight of 1000 seeds, instead, showed a direct effect opposite to the one showed in 1988 (0.278), due to the negative indirect effects exerted via the other three characters (tab. 9), expecially via head sterility (-0.362). This last character however showed, oppositely to the precedent year, a more rilevant direct effect (0.561) not very far from the correlation coefficient with oil content (r= 0.499).

Plant growth stages vs. seeds yield

1987

Among the examined characters, the lenght of period between flowering and physiological ripening showed (fig. 6) the most relevant direct effects (1.176) vs. seeds yield, but with indirect effects via the other characters (tab. 10) that are all negative and extremely variable. The period between flower bud appearance and flowering showed remarkable direct positive effects but also indirect effects via period flowering-ripening (with which it was negatively correlated; r= -0.423) that were negative and relatively high (-0.497).

1988

The interphases flower bud-flowering and flowering-ripening always showed a direct and positive effect on the examined trait (fig. 7), with values always higher than the respective correlation coefficients (tab. 10), above all due to the indirect effects via periods emergence-flower bud (-0.139) and flower bud-flowering (-0.124).

On the contrary, the direct effects of the other two characters have been rather low; only the interval emergence-flower bud pointed out a remarkable indirect positive effect via flower bud - flowering (0.561).

1989

Also in the third year of trial (fig. 8 and tab. 10) the importance of the last interphase in determining the yield was confirmed, while the direct effects of the previous ones resulted lower than the correlation coefficients. This could furtherly assess the role of indirect effects, above all via flowering-ripening, with which all the first three interphases were positively correlated.

Plant growth stages vs. oil content

1987

The direct effects of the lenght of periods between the different growth stages upon oil content have been positive but low (fig. 9), with residual effects, on the contrary, very high (0.909). More remarkable seemed, however, the direct effect of the last interphase (0.404).

1988

The results of path analysis (tab. 11) pointed out the negative direct effect on oil content of the first considered interphase (sowing - emergence; -0.457), with cospicuous indirect effects via flower bud - flowering and flowering - ripening (0.237 and 0.220).

The period between flowering and ripening also showed a high positive direct effect, higher than the correlation coefficient, above all due to the indirect effects via sowing - emergence (-0.117), with which it was positively correlated, and flower bud - flowering (-0.115) with which it was, instead, inversely correlated (fig. 10).

1989

Also in the third year of trial the relatively important direct effect of the interval flowering-ripening on the oil content of Sunflower seeds was confirmed (0.460), even if it was slightly lower than the "r" value (tab. 11 and fig. 11). The results seemed to confirm the negative direct effect of the first interphase, with opposite sign to the correlation, while the interphase flower bud - flowering did not show direct effects but only indirect ones, above all via the trait emergence - flower bud (0.467), with which it was closely correlated (r= 0.843). It may be pointed out, furtherly, a tight positive correlation between the interphase emergence - flower bud and the oil content of seeds, given above all by a strong positive direct effect and by a reduced indirect effect via flowering-ripening.

DISCUSSION AND CONCLUSION

The analysis of simple correlations allowed to point out how in Sunflower seeds yield seems to be depending above all upon the weight of 1000 seeds and the head barren area and, to a smaller extent, upon the head diameter.

The "path analysis", by defining the cause-effect relations of the examined characters, showed a remarkably different frame from the above written one. The results, in fact, always showed for the weight of 1000 seeds a stronger direct effect than the one showed by the other characters, while head sterility and head diameter played above all an indirect role via the weight of 1000 seeds, with which, in all the three-years period, they have always been inversely correlated.

The lenght of the period between the different examined phenological phases also seemed to play some role both on seeds yield and on oil content of seeds.

The simple correlations analysis, in fact, always pointed out a close relation between those two characters and the lenght of the reproductive period (from the appearance of flower bud).

The interpretation of the results of "path coefficient" analysis, however, is made more difficult by the large variability of the correlations between the phenological phases themselves, probably depending upon the climatical course or other hardly identifiable factors, that is moreover testify by the presence of high residual factors.

The performed analysis points out, however, the importance to the yield result of the lenght of the period flowering-ripening, that plays some role with both a strong direct effect and cospicuous indirect effect exerted by all the other growth stages via this one.

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Comunicazione presentata al:

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Tab. 1 - Chemical and physical soil characteristics.

sand	28%
silt	28%
clay	44%
pH	8,61
total $CaCO_3$ (De Astis)	6,80%
active $CaCO_3$ (Drouineau)	4,80%
organic matter (Lotti)	1,30%
total N (Kjeldahl)	1%
assim. P_2O_5 (Olsen)	16,9 ppm
exchang. K_2O (int. met.)	371,9 ppm

Tab. 2 - Correlations among biometric characters and seed yield and oil content (1987).

	Head diameter	Head sterility	Plant height	Seed yield	Oil content (%)
Weight of 1000 seeds	*-0,176 n.s.*	*-0,625 ***	*-0,465 **	*0,698 ***	*-0,083 n.s.*
Head diameter		-0,075 n.s.	0,322 n.s.	0,331 n.s	0,079 n.s.
Head sterility			0,557 **	0,617 **	0,016 n.s.
Plant height				0,007 n.s	0,040 n.s.

Tab. 3 - Correlations among biometric characters and seed yield and oil content (1988).

	Head diameter	Head sterility	Plant height	Seed yield	Oil content (%)
Weight of 1000 seeds	0,029 n.s.	-0,551 **	-0,574 **	0,589 **	-0,428 *
Head diameter		-0,263 n.s.	0,292 n.s.	0,594 **	0,006 n.s.
Head sterility			0,421 *	-0,662 **	-0,314 n.s.
Plant height				-0,205 n.s	0,507 **

Tab. 4 - Correlations among biometric characters and seed yield and oil content (1989).

	Head diameter	Head sterility	Plant height	Seed yield	Oil content (%)
Weight of 1000 seeds	-0,242 n.s.	-0,645 **	-0,361 n.s.	0,672 **	-0,261 n.s.
Head diameter		-0,145 n.s.	0,278 n.s.	0,291 n.s	0,109 n.s.
Head sterility			0,354 n.s.	-0,738 **	0,499 **
Plant height				-0,230 n.s	0,532 **

Tab. 5 - Correlation among Growth Stages lenght and seed yield and oil content (1987).

	Emerg.-fl. buds	Flower buds-flowering	Flow.-rip.	Seed yield	Oil content (%)
Sowing-emergence	-0,498 **	0,742 **	-0,082 n.s.	0,421 *	0,108 n.s.
Emergence-flower buds appear.		0,843 **	-0,321 n.s.	0,451 *	0,077 n.s.
Flower buds appear.-flowering			-0,423 *	0,730 **	0,271 n.s.
Flowering-ripening				0,744 **	0,275 n.s.

Tab. 6 - Correlation among Growth Stages lenght and seed yield and oil content (1988).

	Emerg.-fl. buds	Flower buds-flowering	Flow.-rip.	Seed yield	Oil content (%)
Sowing-emergence	0,382 *	0,356 n.s.	0,256 n.s.	0,407 *	0,111 n.s.
Emergence-flower buds appear.		0,784 **	-0,211 n.s.	0,477 *	0,457 *
Flower buds appear.-flowering			-0,173 n.s.	0,638 **	0,582 **
Flowering-ripening				0,630 **	0,567 **

Tab. 7 - Correlation among Growth Stages lenght and seed yield and oil content (1989).

	Emerg.-fl. buds	Flower buds-flowering	Flow.-rip.	Seed yield	Oil content (%)
Sowing-emergence	0,341 n.s.	0,351 n.s.	0,531 **	0,493 **	0,246 n.s.
Emergence-flower buds appear.		0,843 **	0,447 *	0,486 *	0,634 **
Flower buds appear.-flowering			0,612 **	0,687 **	0,609 **
Flowering-ripening				0,890 **	0,573 **

Tab. 8 - Path coefficient analysis of the direct and indirect effects of biometric characters upon seeds yield.

	1987	1988	1989
Weight of 1000 seeds vs. seeds yield			
direct effect	0,704	0,413	0,551
indirect effect via head diameter	-0,047	0,015	-0,093
indirect effect via head sterility	0,268	0,172	0,205
indirect effect via plant height	-0,226	-0,010	0,009
total (r)	0,698	0,589	0,672
Head diameter vs. seed yield			
direct effect	0,266	0,495	0,385
indirect effect via weight of 1000 seeds	-0,124	0,012	-0,133
indirect effect via head sterility	0,032	0,082	0,046
indirect effect via plant height	0,157	0,005	-0,007
total (r)	0,331	0,594	0,291
Head sterility vs. seed yield			
direct effect	-0,421	-0,311	-0,318
indirect effect via weight of 1000 seeds	-0,440	-0,228	-0,355
indirect effect via head diameter	-0,020	-0,130	-0,056
indirect effect via plant height	0,271	0,008	-0,009
total (r)	-0,617	-0,662	-0,738
Plant height vs. seed yield			
direct effect	0,487	0,018	-0,025
indirect effect via weight of 1000 seeds	-0,327	-0,237	-0,199
indirect effect via head diameter	0,086	0,145	0,107
indirect effect via head sterility	-0,238	0,131	-0,133
total (r)	0,007	-0,205	-0,230

Tab. 9 - Path coefficient analisys of the direct and indirect effects of biometric characters upon oil content.

	1988	1989
Weight of 1000 seeds vs. oil content		
direct effect	-0,166	0,278
indirect effect via head diameter	-0,004	-0,036
indirect effect via head sterility	0,002	-0,362
indirect effect via plant height	-0,259	-0,142
total (r)	-0,427	-0,261
Head diameter vs. oil content		
direct effect	-0,134	0,148
indirect effect via weight of 1000 seeds	-0,005	-0,067
indirect effect via head sterility	0,001	-0,081
indirect effect via plant height	0,132	0,109
total (r)	-0,006	0,109
Head sterility vs. oil content		
direct effect	-0,004	0,561
indirect effect via weight of 1000 seeds	0,092	-0,179
indirect effect via head diameter	0,035	-0,021
indirect effect via plant height	0,190	0,139
total (r)	0,313	0,499
Plant height vs. seed yield		
direct effect	0,452	0,392
indirect effect via weight of 1000 seeds	0,095	-0,100
indirect effect via head diameter	-0,039	0,041
indirect effect via head sterility	-0,002	0,199
total (r)	0,507	0,531

Tab. 10 - Path coefficient analysis of the direct and indirect effects of growth stages lenght upon seeds yield.

	1987	1988	1989
Sowing-emergence vs. seeds yield			
direct effect	0,305	-0,102	0,038
indirect effect via emergence-flower bud appearance	-0,235	0,048	-0,055
indirect effect via flower bud appearance-flowering	0,447	0,255	0,131
indirect effect via flowering-ripening	-0,096	0,206	0,379
total (r)	0,421	0,407	0,493
Emergence-flower bud appearance vs. seeds yield			
direct effect	0,472	0,125	-0,161
indirect effect via sowing-emergence	-0,152	-0,039	0,013
indirect effect via flower bud appearance-flowering	0,508	0,561	0,315
indirect effect via flowering-ripening	-0,377	-0,170	0,319
total (r)	0,451	0,477	0,486
Flower bud appearance-flowering vs. seeds yield			
direct effect	0,603	0,715	0,374
indirect effect via sowing-emergence	0,226	-0,036	0,013
indirect effect via emergence-flower bud appear	0,398	0,098	-0,136
indirect effect via flowering-ripening	-0,497	-0,139	0,436
total (r)	0,730	0,638	0,687
Flowering-ripening vs. seeds yield			
direct effect	1,176	0,806	0,713
indirect effect via sowing-emergence	-0,025	-0,026	0,020
indirect effect via emergence-flower bud appear	-0,152	-0,026	-0,072
indirect effect via flower bud appearance-flowering	-0,255	-0,124	0,229
total (r)	0,744	0,630	0,890

Tab. 11 - Path coefficient analysis of the direct and indirect effects of growth stages lenght upon oil conten

	1987	1988	1989
Sowing-emergence vs. oil content			
direct effect	0,212	-0,457	-0,157
indirect effect via emergence-flower bud appearance	-0,125	0,111	0,189
indirect effect via flower bud appearance-flowering	0,054	0,237	-0,030
indirect effect via flowering-ripening	-0,033	0,220	0,244
total (r)	0,108	0,111	0,246
Emergence-flower bud appearance vs. oil content			
direct effect	0,251	0,290	0,554
indirect effect via sowing-emergence	-0,106	-0,175	-0,054
indirect effect via flower bud appearance-flowering	0,062	0,523	-0,072
indirect effect via flowering-ripening	-0,130	-0,181	0,206
total (r)	0,077	0,457	0,634
Flower bud appearance-flowering vs. oil content			
direct effect	0,073	0,667	-0,085
indirect effect via sowing-emergence	0,157	-0,163	-0,055
indirect effect via emergence-flower bud appearance	0,212	0,227	0,467
indirect effect via flowering-ripening	-0,171	-0,149	0,282
total (r)	0,271	0,582	0,609
Flowering-ripening vs. oil content			
direct effect	0,404	0,860	0,460
indirect effect via sowing-emergence	-0,017	-0,117	-0,083
indirect effect via emergence-flower bud appearance	-0,081	-0,061	0,248
indirect effect via flower bud appearance-flowering	-0,031	-0,115	-0,052
total (r)	0,275	0,567	0,573

Fig. 1a – Ten days values of rainfall and temperatures recorded at Sparacia (AG) in 1987

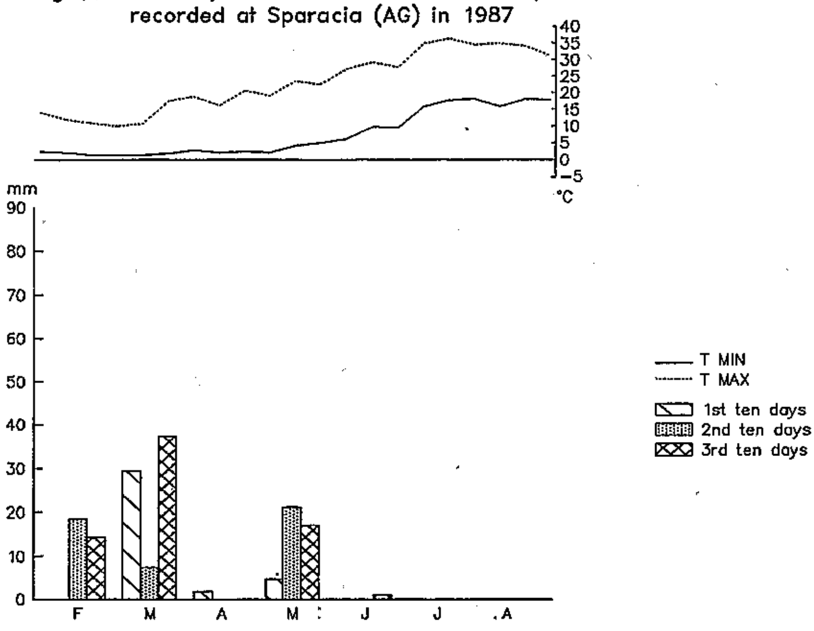


Fig. 1b – Ten days values of rainfall and temperatures recorded at Sparacia (AG) in 1988

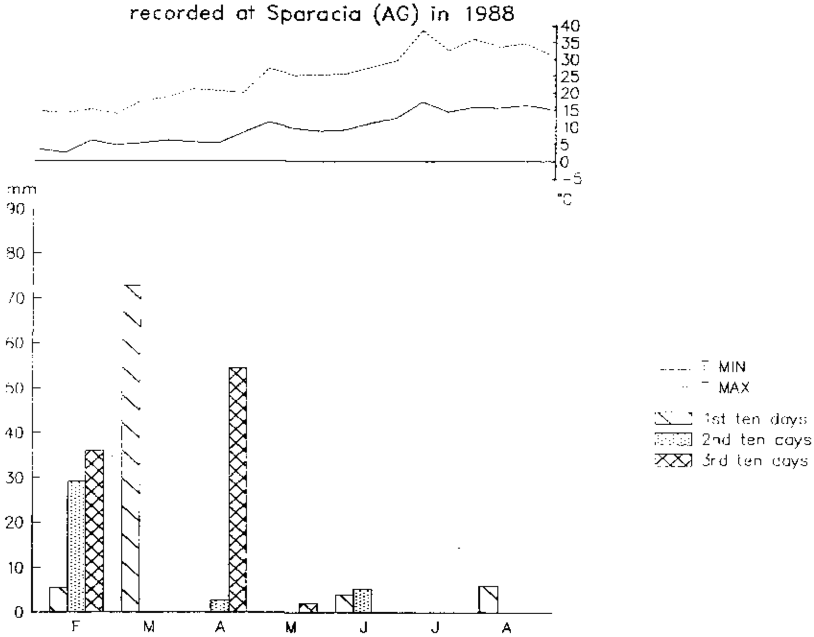
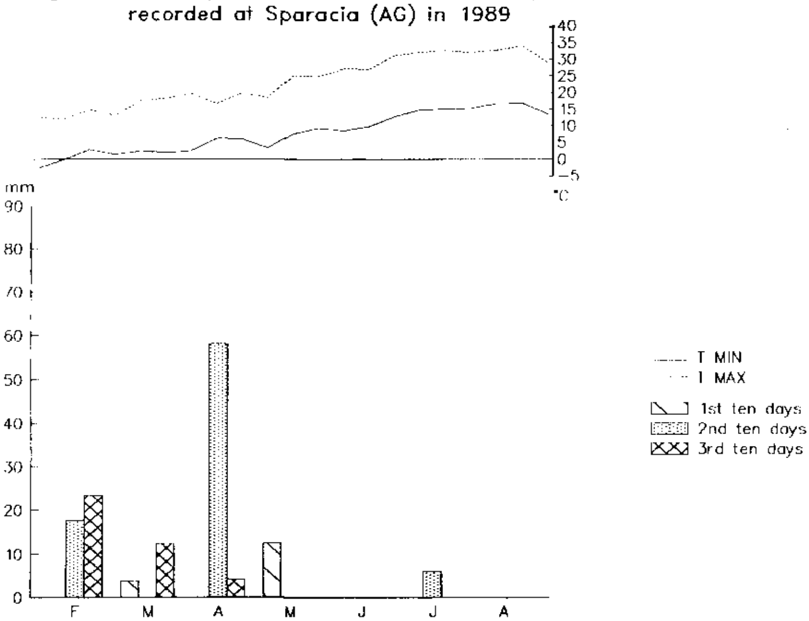


Fig. 1c – Ten days values of rainfall and temperatures recorded at Sparacia (AG) in 1989



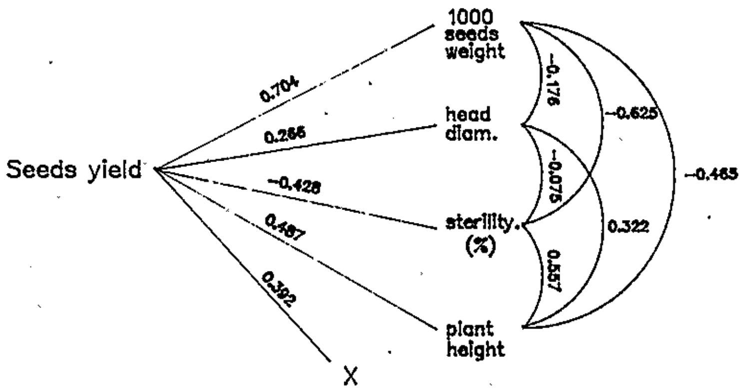


Fig. 2 – Path diagram and coefficients of biometric characters influencing seed yield (1987).

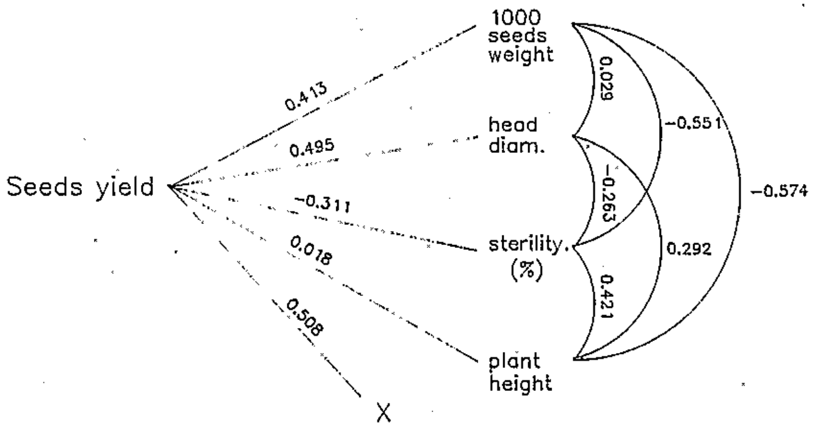


Fig. 3 – Path diagram and coefficients of biometric characters influencing seed yield (1988).

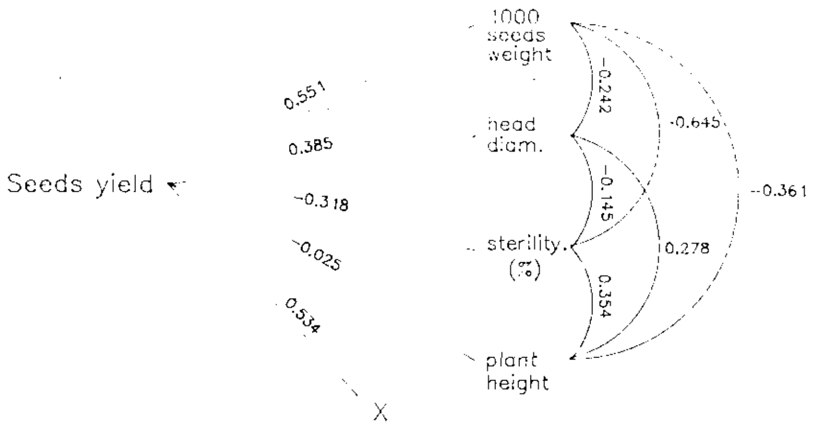


Fig. 4 — Path diagram and coefficients of biometric characters influencing seed yield (1989).

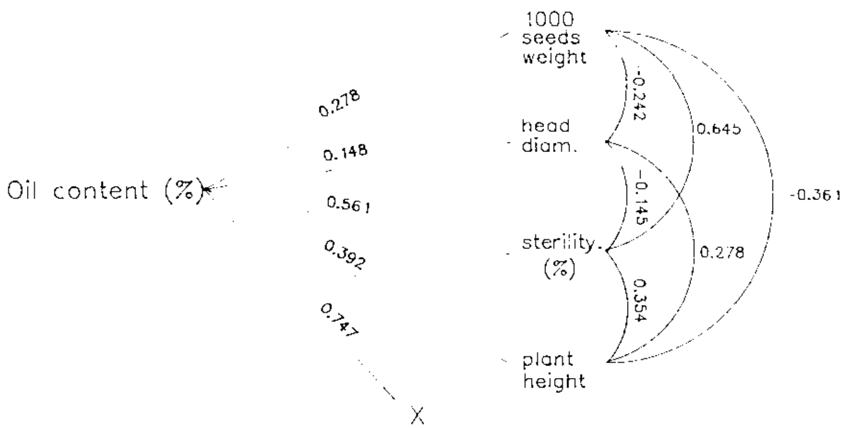


Fig. 5 — Plant diagram and coefficients of biometric characters influencing oil content (1988).

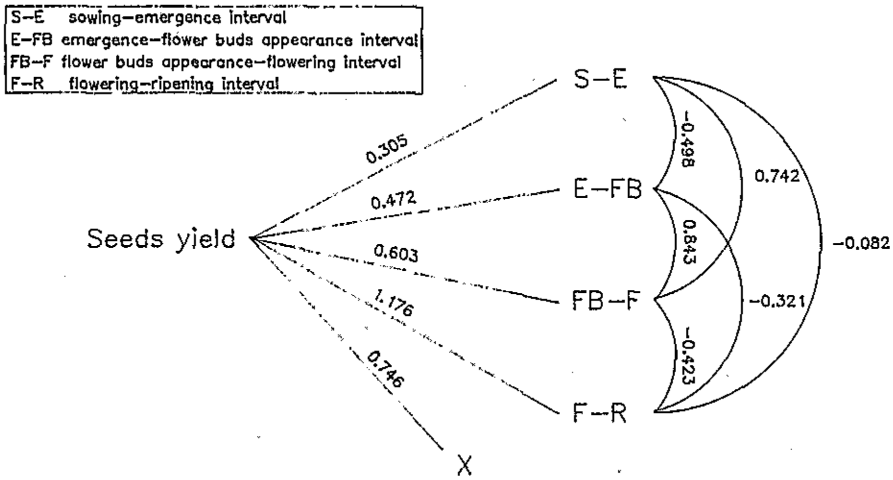


Fig.6 – Path diagram and coefficients of growth stages lenghts influencing seed yield (1987).

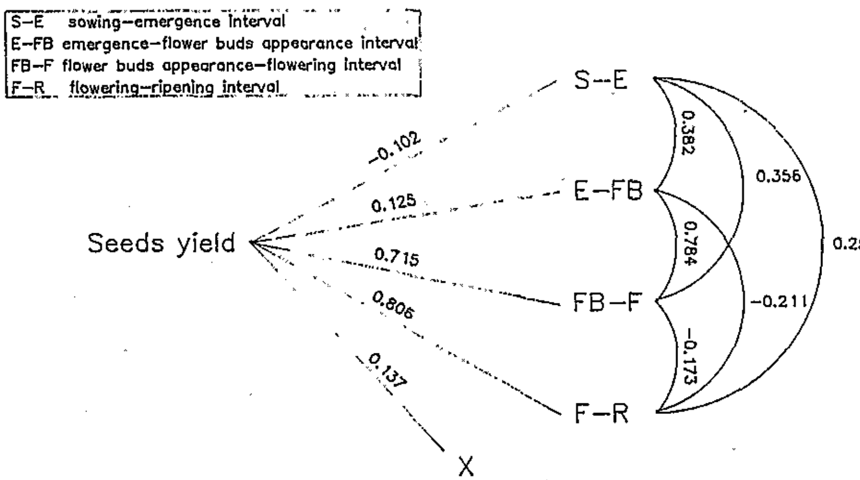


Fig.7 – Path diagram and coefficients of growth stages lenghts influencing seed yield (1988).

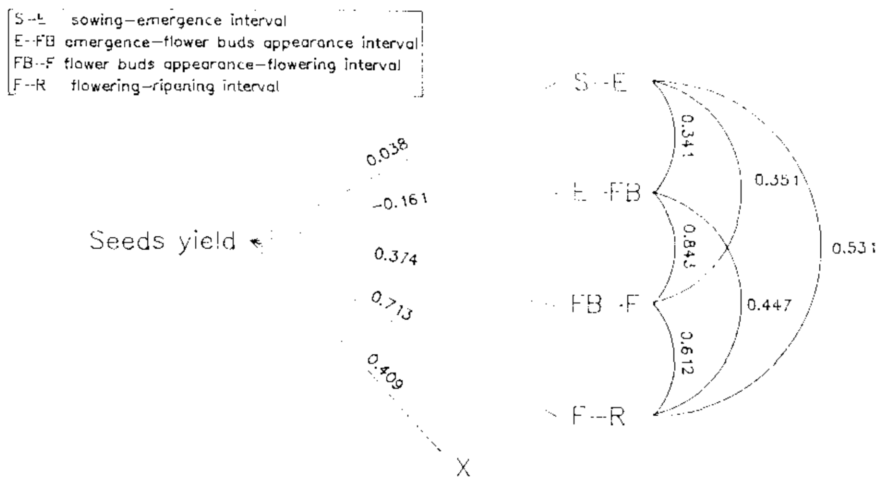


Fig.8 – Path diagram and coefficients of growth stages lenghts influencing seed yield (1989).

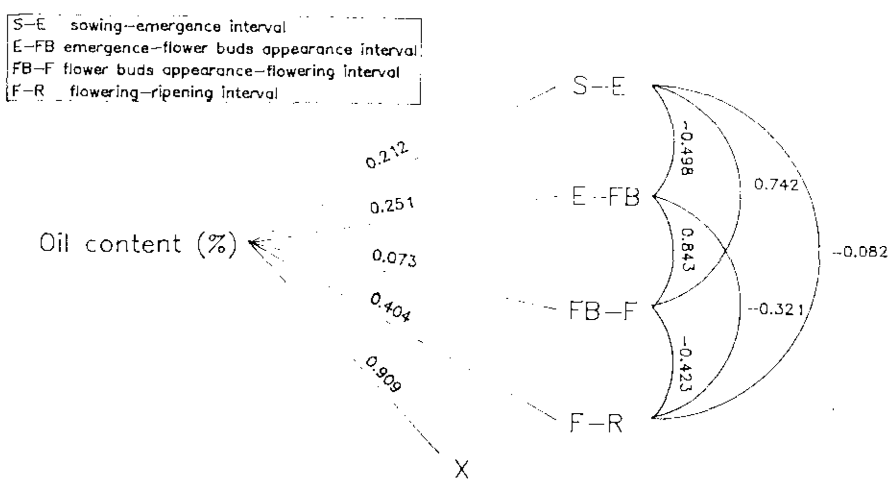


Fig. 9 – Path diagram and coefficients of growth stages lenghts influencing oil content (1987).

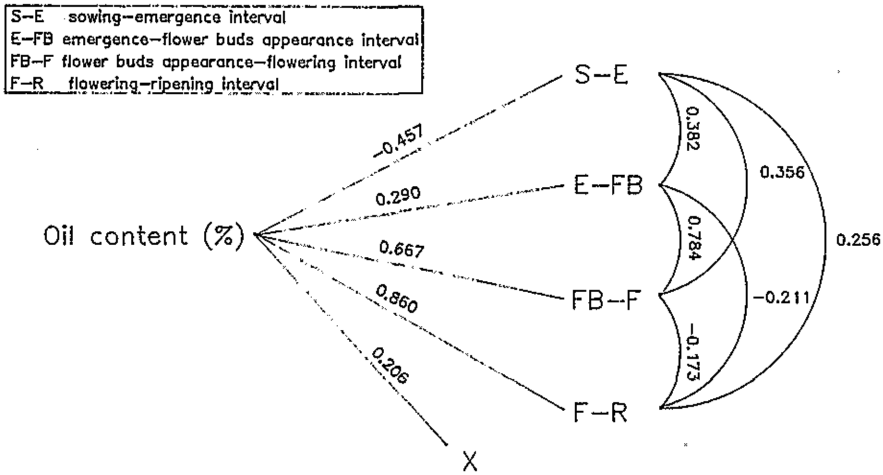


Fig. 10 – Path diagram and coefficients of growth stages lenghts influencing oil content (1988).

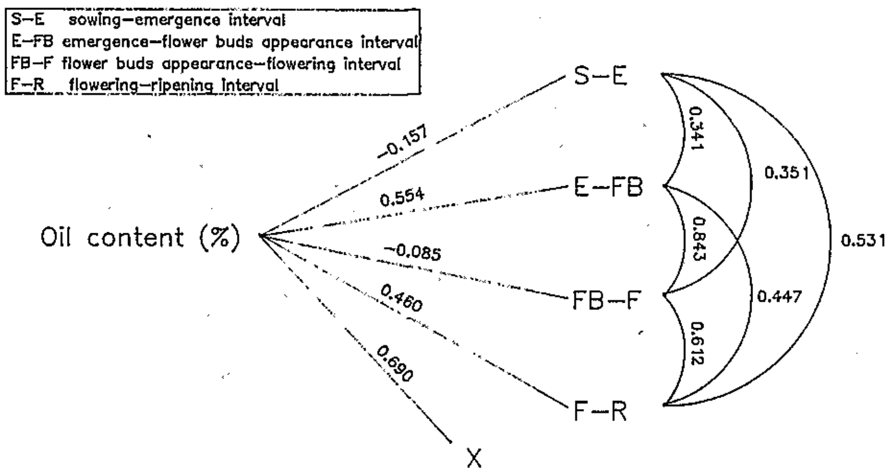


Fig. 11 – Path diagram and coefficients of growth stages lenghts influencing oilcontent (1989).