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Genetic progress of soybean varieties released during 1969 to 2008 in India

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Abstract

The study undertaken to assess the genetic changes on yield, agronomic traits and foliar diseases during the last 39 years (1969 to 2008), revealed 103.5 % yield improvement over the years @ 2.6 % per year. The annual genetic gain in seed yield of soybean varieties released in India during this period was approximately 23 kg ha^{-1}. This yield increase was assigned to increase in number of pods and seeds per plant. Seeds per plant increased by 1.56 % per year. Foliar diseases decreased consistently over the period. Varieties namely Kalitur, Bragg, Punjab 1, PK 308, PK 471, JS 71-05, NRC 2, PS 1042, JS 93-05 and PS 1347 were stable over the seasons for the yield. Varieties namely Kalitur, Bragg, Punjab 1 and PS 1042 were found suitable in unfavorable seasons while varieties *viz*., PK 308, PK 471, JS 71-05, NRC 2, JS 93-05 and PS 1347 were found suitable in favorable seasons. None of the varieties was found consistently superior for all the characters in all the seasons.

Key words: Soybean, *Glycine max*, variety development, yield gain, foliar disease

Introduction

In India, 97 varieties of soybean were released for cultivation from 1969 to 2008. The successive release of new soybean varieties for cultivation may imply improved yield potential of new varieties. However, even after the release of 54 varieties in last two decades (1990-2009) the average productivity has been hovering around 10.00 ± 1.26 q ha^{-1}. This raises concern regarding genetic progress in yield potential of the varieties so far released in India. Therefore, the study was undertaken to assess the genetic changes on yield and agronomic traits along with foliar diseases during the last 39 years (from 1969 to 2008).

Materials and methods

Seventeen out of 97 soybean varieties developed between 1969 and 2008 which were commonly grown in the country during this period, were selected for the study (Table 1). The experiment was conducted in a Randomized Block Design with three replications during 2007 to 2009 at the experimental farm of the Directorate of soybean Research, Indore (M.P.) which is situated at 22^{o} 4'37''N latitude, 75^{o} 52'7''E longitude and altitude of 540 m above the mean sea level. The varieties were sown in six five meter long rows (spacing 45 cm x 10 cm). The experimental sites were having deep black-cotton soils with pH 7.6 to 8.1, low to medium in organic carbon and available phosphorus and high in potassium (Typic Chromusterts and Lithic Vertic Ustochrepts). Before sowing, 20 kg ha^{-1} Nitrogen, 60 kg ha^{-1} Phosphorus and 20 kg ha^{-1} Potassium were applied in the form of commercial fertilizers. Experiments were generally rainfed with life saving irrigation when needed.

Seed yield was recorded on net plot basis (13.5 m^2) and then converted in to kg ha^{-1}. Phenological measurements such as days to flowering were measured at R2 stage [1] and other parameters like plant height (cm), nodes/plant, pods/plant and seeds/plant were measured at maturity (R8 stage). Air dried seeds were weighted for seed yield.

Observations on bacterial pustule (causal organism: *Xanthomonas campestris*) and Myrothecium leaf spot (causal organism: *Myrothecium roridum*) were taken on plants at the R5 stage of development using standard rating scale 0 to 9.

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Table 1. Name of soybean varieties, year of release, growth habit and area of adaptability

S.No.	Variety	Year of release	Pedigree	Growth type	Area of adaptability
1	Kalitur	1969	Indigenous variety	Semi-determinate	Madhya Pradesh
2	Bragg	1969	Introduction from USA	Determinate	Whole India
3	Improved Pelican	1969	Introduction from USA	Semi-determinate	Southern zone
4	Hardee	1976	Introduction from USA	Determinate	Southern zone
5	Punjab-1 variety	1978	Selection form Nanking	Semi-determinate	Central, northern plain & northern hill zones
6	Durga	1981	EC 14437 x Bragg	Semi-determinate	Central zone (JS 72-280)
7	Pusa 40	1981	8-3 x Lee	Determinate	Southern zone
8	PK308	1984	T 31 x Hardee	Determinate	Northern hill zone and northern plain zone
9	PK471	1988	Hardee x Punjab- 1	Determinate	Southern zone
10	JS 71-05	1990	Selection from exotic material	Determinate	Malwa plateau of MP
11	JS335	1993	JS78-77x JS71-5	Determinate	Central zone
12	NRC 2 (Ahilya-1)	1997	Mutant of Bragg	Determinate	Madhya Pradesh
13	PS 1042	1997	Bragg x PK 416	Determinate	Northern plain zone
14	NRC 37 (Ahilya 4)	2001	Gaurav x Punjab 1	Semi-determinate	Madhya Pradesh, Rajasthan, Maharashtra (Vidharbha & Marathwada), Bundelkhand region of Uttar Pradesh
15	JS 93-05	2002	Selection from PS 73-22	Determinate	Central zone (Maharashtra, Madhya Pradesh, Rajasthan,Gujarat and Bundelkhand region of Uttar Pradesh)
16	JS 95-60	2006	Selection from PS 73-22	Determinate	Madhya Pradesh
17	PS 1347	2008	PS 1024 x PK 472	Semi-determinate	North plain zone

The means of the traits were plotted against the year of variety release. A straight line was fitted through the points using simple linear regression. The degree of association between the year of variety release and each trait was examined by calculating the simple linear correlation coefficient (r) with n-2 degrees of freedom. Variety means across the years were used to calculate correlations among the traits. Varieties were analyzed for stability parameters following Eberhart and Russell model [2].

Results and discussion

Varieties differed from each other significantly for all traits except 100-seed weight (Table 2), indicating the presence of substantial variability for the different traits among them. Similarly, seasons in which the genotypes were grown also differed significantly for all the traits except nodes plant^{-1}. Further variance due to G x E interactions was highly significant for all the characters indicating the differential response of genotypes in expression of the characters to varying seasons.

Plant height differences among varieties were significant, ranging from 33.78 cm to 52.44 cm (Table 2). The decrease in plant height during 1969 to 2008 was 26.31% (Fig. 1) and number of nodes was 14.13% (Fig. 2). Plant height had positive association ($P<0.01$) with nodes plant^{-1} (Table 3) and negatively associated with year of release ($P<0.01$) and seeds per plant and yield ($P<0.05$).

Table 2. Mean squares for varieties and the interactions of Genotype x Environment from the combined analysis of variance

Source of variation	df	Height (cm)	Nodes $plant^{-1}$ (No.)	Days to flowering	Pods $plant^{-1}$ (No.)	Seeds $plant^{-1}$ (No.)	100-seed weight (g)	Yield (kg ha^{-1})	Bacterial pustule (1-9)	Myro-thecium leaf spot (1-9)
Varieties	16	146.97^{+}	12.311**	104.119**	327.527**	1655.063**	1.729^{ns}	570709.828**	3.975**	0.501**
Years	2	136.93**	1.987^{ns}	52.878**	1341.203**	6226.205**	7.855*	7161760.389**	7.458*	9.779**
Variety x years	32	82.83**	3.306**	10.651**	123.277**	537.677**	2.142**	121928.373**	0.833**	0.280**
Environment + (variety x years)	24	121.85+	4.574^{ns}	18.608**	276.136**	1235.753*	3.510^{+}	759384.530**	1.733+	1.189**
Years (linear)	1	273.86**	3.974^{ns}	105.756**	2682.405**	12452.410**	15.710**	14323520.779**	14.917**	19.558**
Variety x year (linear)	16	93.28^{ns}	3.388^{ns}	20.472**	120.162^{ns}	569.530^{ns}	2.297^{++}	104867.045^{ns}	0.569^{ns}	0.451**
Pooled deviation	17	68.12	3.035	0.781	118.957	476.070	1.870	130813.836	1.034	0.103
Pooled error	96	8.414	0.923	0.726	51.493	113.595	0.104	20907.020	0.177	0.100

*p=0.05, **p=0.01; ++ Significant only when tested against pooled error.

The yield varied significantly among the 17 varieties, ranging from 477.06 kg ha^{-1} to 1968.15 kg ha^{-1} (Fig. 3, Table 3). There was a 103.5 % yield improvement @2.6 % per year across 39 years of plant breeding and selection efforts. The annual genetic gain in seed yield was approximately 23 kg ha^{-1} (Fig. 3). The pod number per plant, however, did not show a significant increase across the 39 year period (Fig. 4), whereas the seed number per pod increased from 1.97 to 2.39 seeds per pod during the same period (Fig. 5). There was no consistent relationship between year of variety release and seed weight (Fig. 6, Table 4).

Seed yield gain (2.6 % per year or 23 kg ha^{-1} $year^{-1}$) in India from 39 year efforts of plant breeding and selection was quite impressive and higher than the yield reported earlier in India [3] and other soybean growing countries of the world. In USA [4] annual increase in seed yield as 0.9% during a 47 year period between 1923 and 1970, [5] 0.6% between1923 to 1974, [6] at the rate of 0.7 % between 1942 and 1973 [7] an annual gain of 0.2 % in 240 varieties released from 1902 to 1977. In Canada [8] 41 cultivars released from 1934 to 1992, showed yield improvement of about 0.5% per year [9]. In Northeast China [10] using 45 representative soybean cultivars for 3 consecutive years, observed positive correlation between seed yield and year of cultivar release and reported 0.58% average annual increase. However, in Brazil, the yield gain varied from 0.0 to 3.49% per yesr depending on the region and maturity group of soybean [11].

Seeds per plant ranged from 50.67 to 126.22 (Table 2) and differed significantly among varieties. It was positively correlated (P<0.01) with year of release of variety (Fig. 5, Table 3). The increase in seeds per plant was observed to be 1.56 % per year across the period under study (Fig. 7).

Current study clearly indicated that increase in yield over the years was mainly on account of increase in number of seeds per plant but not by increase in seed size as there was no significant correlation found with the year of release. Similar results were reported elsewhere [9, 10, 12]. It was stated that seed size was more likely to fluctuate with changes in environment than seed number per plant. Similarly, in present study no relationship between year of release of variety and pods per plant was observed indicating no role of pod numbers in yield gain but the number of the seeds per plant. Therefore, maximum yield gain has come from the increase in number of seeds per plant.

Table 3. Mean agronomic traits and stability of yield of soybean varieties released in India during 1969 to 2008

Varieties	Yield (kg ha^{-1})			Days to flowering	Height (cm)	Nodes plant^{-1} (No.)	Pods plant^{-1} (No.)	Seeds plant^{-1} (No.)	100-seed weight (g)	Bacterial pustule (1-9)	Myrothecium leaf spot (1-9)
	Mean	s^2di	bi								
Kalitur	477.067	25507.224	0.470*	33.778	61.222	16.556	25.000	50.667	10.884	1.178	1.311
Bragg	1213.169	-14027.380	0.414**	39.556	50.444	11.000	26.222	54.111	12.266	1.489	2.156
Imp. Pelican	1110.864	61563.131*	0.990**	52.444	58.333	14.889	38.333	73.111	9.971	3.444	1.756
Hardee	1019.506	135400.134**	1.336**	45.111	49.111	14.333	45.222	82.889	11.326	1.711	2.511
Punjab -1	1218.106	-17980.591	0.807**	50.444	52.889	14.889	34.556	69.333	10.241	4.422	1.622
Durga	803.292	303895.640**	1.087	43.000	51.111	13.556	23.444	49.444	10.303	2.244	2.111
Pusa 40	1049.630	639040.815**	0.815	48.111	45.444	12.222	57.333	119.333	10.232	2.400	1.844
PK 308	1032.099	35619.923	1.340**	47.444	38.889	9.889	32.556	75.333	10.556	4.911	1.933
PK 471	1233.251	-19962.302	1.235**	47.222	39.333	11.889	38.556	74.222	10.903	1.444	1.578
JS 71-05	1783.291	-9146.386	1.485**	37.667	45.222	11.778	33.222	75.000	11.682	1.756	1.400
JS 335	1844.198	155403.559**	0.713	44.444	41.111	11.889	50.333	126.222	11.878	1.178	1.844
NRC 2	1188.972	-9686.207	1.318**	35.667	40.333	10.111	40.556	78.444	11.427	1.622	1.889
PS 1042	1041.233	16180.530	0.711**	41.444	40.444	10.667	35.000	87.111	10.914	1.644	1.267
NRC 37	1892.591	233049.753**	1.510**	45.889	49.778	16.111	59.667	113.000	12.312	1.133	1.756
JS 93-05	1960.988	32736.000	1.090**	40.889	40.889	11.667	36.667	94.000	10.199	1.444	1.311
JS 95-60	1968.149	321716.822**	0.538	31.556	37.333	11.667	46.667	115.556	11.904	1.000	1.000
PS 1347	1399.094	-20894.795	1.141**	46.889	47.333	12.556	32.667	77.444	11.261	1.578	1.044
Grand mean	1307.971			43.033	46.425	12.686	38.588	83.248	11.074	2.035	1.667
SEm	304.401			0.744	6.946	1.466	9.179	18.363	1.151	0.856	0.271
CD at 5%	854.518			2.089	19.500	4.116	25.768	51.550	3.230	2.402	0.760
CD at 1%	1131.321			2.765	25.816	5.450	34.116	68.249	4.277	3.180	1.006

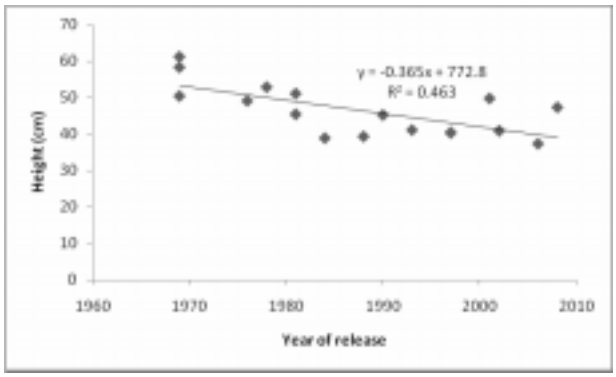

Fig. 1. Relationship between year of release and plant height (cm)

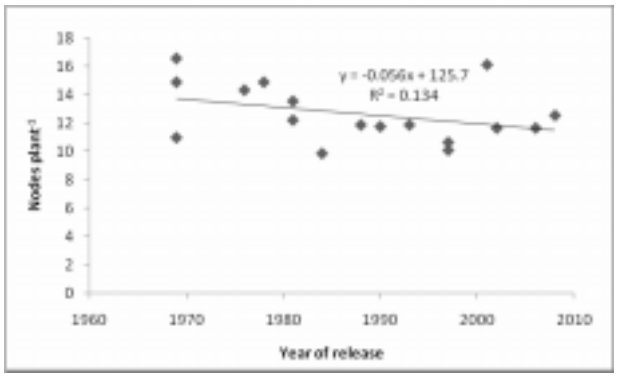

Fig. 2. Relationship between year of release and nodes plant^{-1}

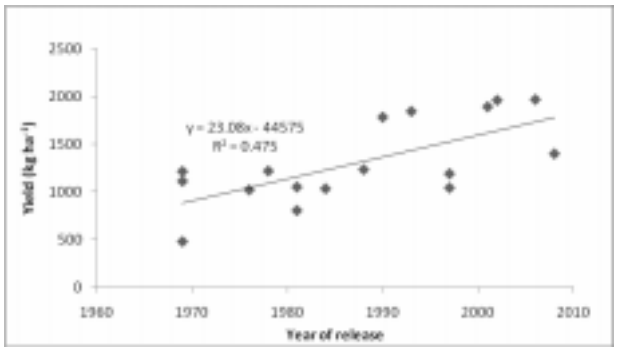

Fig. 3. Relationship between year of release and yield (kg ha^{-1})

There were significant differences among varieties for both bacterial pustule and Myrothecium leaf spot diseases (Figs. 8 & 9). The disease score ratings of both the foliar diseases decreased with year of release of variety. Myrothecium leaf spot was negatively correlated ($P < 0.05$) with year of release of variety, with a linear decline of 0.9% per year over the 39 years period (Fig. 9). However, no significant correlation was

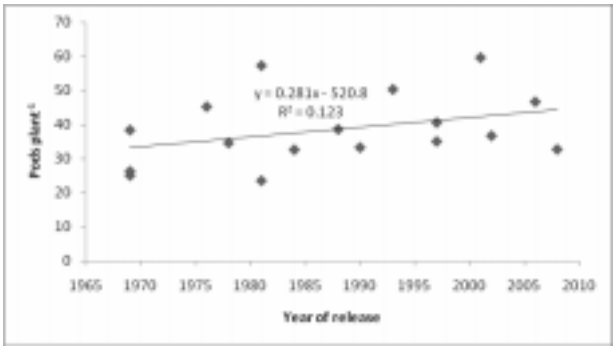

Fig. 4. Relationship between year of release and pods plant^{-1}

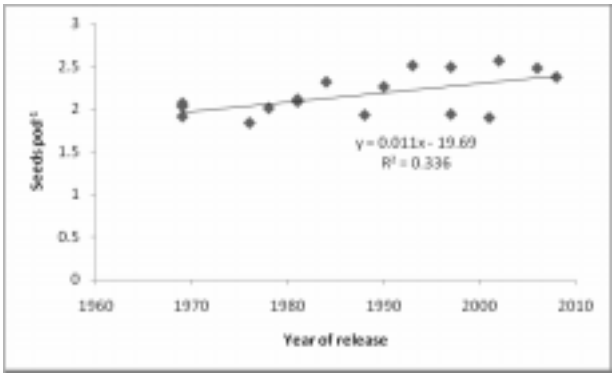

Fig. 5. Relationship between year of release and seeds pod^{-1}

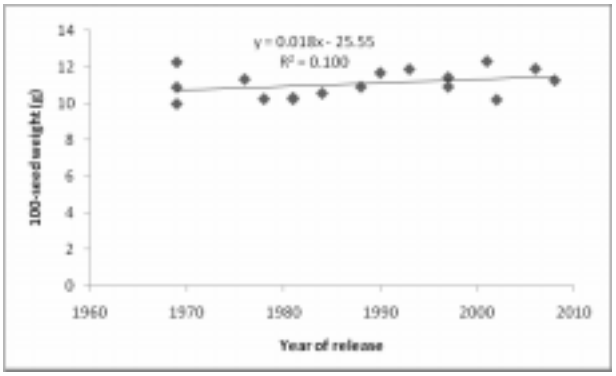

Fig. 6. Relationship between year of release and 100-seed weight (g)

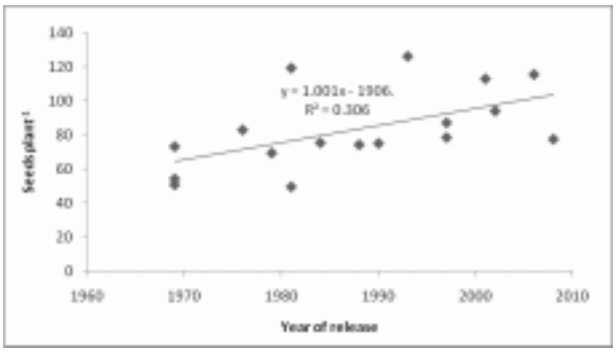

Fig. 7. Relationship between year of variety release and seeds plant^{-1}

observed with other agronomic characteristics (Table 2). Bacterial pustule also followed decreasing trend of 1.19% per year but it was not significant with the year of release. However, bacterial pustule had positive association (P<0.05) with days to flowering (Fig. 10) but negative with 100-seed weight (Table 2).

Both the foliar diseases were relatively less severe in more recently released varieties as compared to old varieties over the period of 39 years in India. Seed isoflavone concentration significantly increased over 58 years of soybean breeding for yield [13]. Isoflavone was found positively associated with N-fixation and disease resistance [14, 15]. This may explain the increase of resistance in varieties consistently with the year of release.

Decrease in plant height over the years provided lodging resistance (Fig. 11) to the varieties. A tendency towards decreased plant height with year of variety release was also reported by others [5, 8, 10]. The correlation between height and lodging score was also reported [4, 9, 10]. They suggested that there may be several coordinated ways or endo-mechanisms regulating the resistance at the whole plant level.

From the present study, ten varieties, *viz*., Kalitur, Bragg, Punjab 1, PK 308, PK 471, JS 71-05, NRC 2, PS 1042, JS 93-05 and PS 1347 deviated non-significantly from zero ($s^2d = 0$) hence, they are stable over the seasons for the yield. To have higher, production, soybean varieties stable over varied seasons are required. Soybean breeders in USA have increased the yield potential of soybean varieties by 25% during a 50 year period and at the same time the phenotypic stability for yield across a wide range of environments has been maintained [5]. In China, yield stability was attributed to the stable pod production across different environments [11].

None of the variety was found average responsive and suitable for all the seasons. However, four varieties *viz*., Kalitur, Bragg, Punjab 1 and PS 1042 were suited to unfavorable season (bi < 1*) while six varieties *viz*., PK 308, PK 471, JS 71-05, NRC 2, JS 93-05 and PS 1347 were found suitable to favorable season (bi > 1*). JS 93-05 and PS 1347 recorded higher mean value than the grand mean. Study concluded that none of the varieties was found consistently superior for all the characters in all the seasons. The stable varieties identified can be used as parents in future breeding programme for development of suitable genotypes for cultivation under diverse environments.

Table 4. Correlation coefficient of agronomic characteristics of soybean varieties released during 1969 to 2008

	Year of release	Height (cm)	Nodes plant^{-1} (No.)	Pods plant^{-1} (No.)	Seeds plant^{-1} (No.)	100-seeds weight (g)	Days to flowe-ring	Yield (kg ha^{-1})	Days to maturity	Bacterial pustule (1-9)	Myro-thecium leaf spot (1-9)
Height (cm)	–0.678**										
Nodes plant^{-1}	–0.362	0.820**									
Pods plant^{-1}	0.350	–0.299	0.086								
Seeds plant^{-1}	0.554*	–0.514*	–0.146	0.897**							
100-seed wt (g)	0.312	–0.213	–0.114	0.260	0.266						
Days to flowering	–0.235	0.196	0.218	0.208	0.053	–0.469					
Yield (kg ha^{-1})	0.691**	–0.503*	–0.213	0.490*	0.657**	0.465	–0.131				
Days to maturity	–0.713**	0.691**	0.531*	–0.150	–0.366	–0.106	0.241	–0.726**			
Bacterial pustule (1-9)	–0.389	0.144	–0.019	–0.202	–0.261	–0.605*	0.598*	–0.331	0.039		
Myrothecium leaf spot (1-9)	–0.575*	0.185	0.051	0.085	–0.163	0.013	0.324	–0.341	0.537*	0.246	
Lodging score	–0.436	0.499*	0.623**	–0.047	–0.138	–0.313	0.077	–0.299	0.329	0.062	0.057

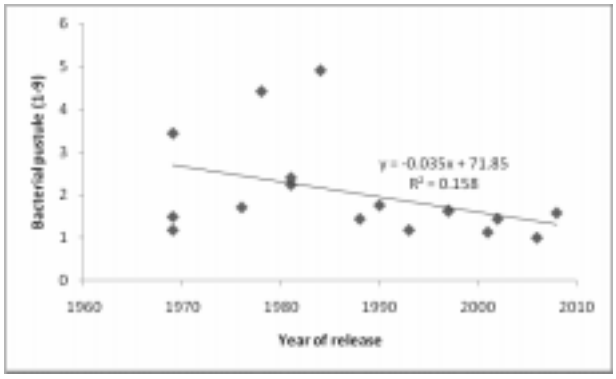

Fig. 8. Relationship between year of release and Bacterial pustule (rating score 0-9)

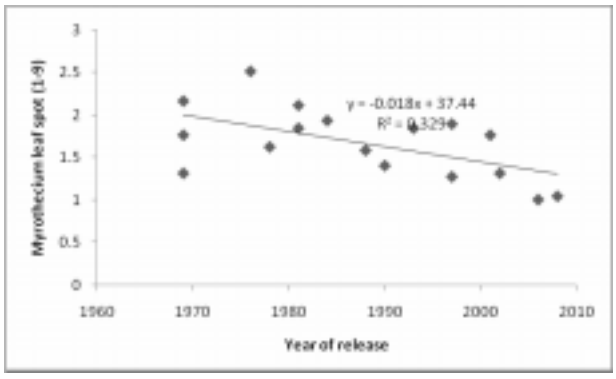

Fig. 9. Relationship between year of release and Myrothecium leaf spot (rating score 0-9)

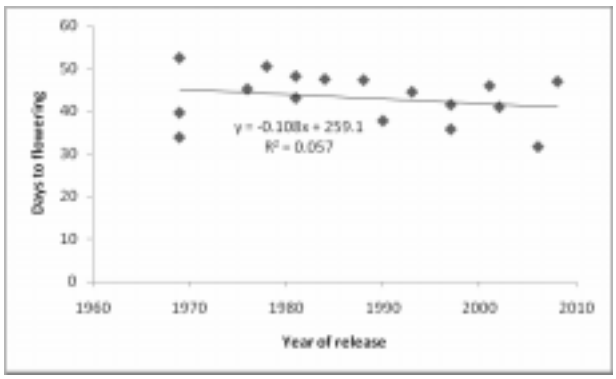

Fig. 10. Relationship between year of release and days to flowering

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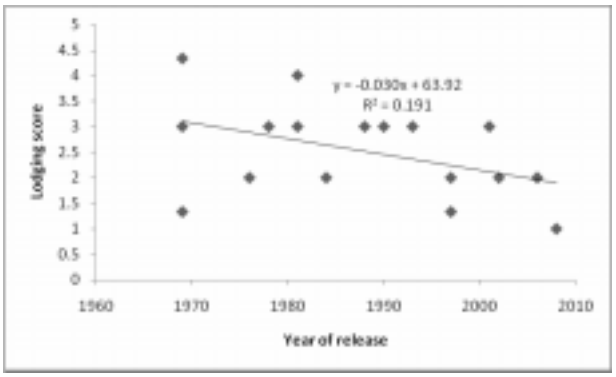

Fig. 11. Relationship between year of release and lodging score (1-5)

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