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THE EXPRESSION AND INFLUENCE ON YIELD OF THE 'DOUBLE-PODDED' CHARACTER IN CHICKPEAS (*CICER ARIETINUM* L.)

A.R. SHELDRAKE, N.P. SAXENA and L. KRISHNAMURTHY

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad-500 016, A.P. (India)

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ABSTRACT

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The number and percentage of nodes bearing two pods in 'double-podded' cultivars of chickpeas grown in northern India (at Hissar) and peninsular India (at Hyderabad) were compared. At Hissar 11% of the pod-bearing nodes were double-podded; at Hyderabad 28% were double-podded on early-sown and 49% on late-sown plants. In all cases the number of double-podded nodes per plant was similar, but different numbers of single-podded nodes per plant were formed, depending on the length of the growing season. At Hyderabad the percentage of double-podded nodes was not significantly affected by population-density nor by shading the plants throughout the reproductive phase. Partial defoliation of the plants reduced the percentage of double-podded nodes, as did the removal of all flowers from the plants for the first two to four weeks of the reproductive phase. The conversion of 'double-podded' plants to 'single-podded' plants by cutting off one of the flowers at every double-flowered node had no effect on yield at a location in the Himalayas where the double-podded character was poorly expressed, but at Hyderabad the yield of the 'single-podded' plants was significantly reduced compared with the 'double-podded' controls. The results indicate that the double-podded character can confer an advantage in yield of about 6 to 11% under conditions in which the character is well-expressed.

INTRODUCTION

Most cultivars of chickpea (*Cicer arietinum* L.) produce a single flower at each flowering node, but some produce two flowers and have the potential to form two pods per node (Athwal and Brar, 1964; Nazir Ahmed, 1964). Although these are generally referred to as 'double-podded' cultivars, under most circumstances two pods are produced at only a minority of the pod-bearing nodes.

We compared the expression of the 'double-podded' character in the field at two locations, one at Hissar in the North, in a region where some of the best yields of chickpeas in India are obtained (Argikar, 1970), and at Hyderabad in peninsular India where the chickpea-growing season is shorter and warmer (Van der Maesen, 1972). We also investigated the effects of a number of environmental and physiological factors on the expression of this character, and attempted to assess its contribution to yield by converting 'double-podded' plants to 'single-podded' plants by cutting off one of the flowers at each double-flowered node. The latter experiments were carried out at Hyderabad and in a Himalayan valley which is sufficiently cool for chickpeas to be grown during the hot season in India.

MATERIALS AND METHODS

Experiments were carried out at three locations: in peninsular India at ICRISAT Center (17°32'N, 78°16'E) near Hyderabad on a Vertisol (fine clayey, calcareous, Typic Chromustert), in northern India at Hissar (29°10'N, 75°44'E) on an Entisol (coarse loamy, calcareous, Typic Camborthids) and in the Lahaul valley (western Himalayas) at Dalang (32°35'N, 77° 0'E, altitude 3140 m) on an Entisol (sandy loam, Typic Eutrochrets). In all cases phosphorus was supplied at the rate of 50 kg P_2O_5 (22 kg P) ha^{-1} in the form of superphosphate. At Hyderabad and Hissar, the roots were well nodulated, but at Dalang nodulation was sparse. In all trials, seeds were sown by hand at a spacing of 30 × 10 cm (except in the plant population trial at Hyderabad) with two seeds per hill; the seedlings were thinned to one per hill two to three weeks after sowing. In both 1975 and 1976 the trials at Hyderabad were lightly irrigated immediately after sowing to ensure good germination, and at Hissar a pre-sowing irrigation was given; thereafter no irrigation was supplied. The crop at Dalang received no irrigation. At all locations the crop was protected against pests by sprays of endosulfan.

EXPERIMENTS AT HYDERABAD

Comparison of cultivars

We compared the expression of the double-podded character and the yield of cvs JG-62, P-272, P-502, P-436 and Pant G-120, which are all 'early'. The cultivars were sown in a randomized block design (plot size 5.1 × 4 m) with three replications on 9 November 1976. Flowering began between 30 December and 4 January 1977. At harvest, on 28 February, border rows were discarded and yield was recorded from a net plot area of 16 m^2. The numbers of nodes bearing one or two pods were recorded from a sample of 20 plants per plot. A similar procedure was followed at harvest in all the trials described below, unless otherwise indicated. In all trials, sun-dry weights were corrected to oven-dry weights on the basis of sub-sample data for each plot or sub-plot.

Effect of population density

The effect of population density on the expression of the double-podded character was investigated with cvs JG-62 and P-436 sown on 17 November 1976 (harvested 1 March 1977) in a split-plot design (three replications) with spacings in the main plots and cultivars in the sub-plots (sub-plot size: 4×3 m). The spacings, which all had a rectangularity of 3:1, were 61.2×20.4 cm (8 plants m^{-2}), 37.5×12.5 cm (21 plants m^{-2}), 30×10 cm (33 plants m^{-2}), 24.5×8.2 cm (50 plants m^{-2}) and 17.3×5.8 cm (100 plants m^{-2}).

Effects of flower removal, defoliation and shading

The effects of these treatments on the expression of the double-podded character and yield of cv. JG-62 were studied in experiments sown on 5 October 1976 (harvested 15 February 1977). Each of these experiments was carried out in a randomized block design with three replications. For the flower removal and defoliation trials the net plot size (excluding border rows) was 3.3 m^2 and for the shading trial 13 m^2. The treatments in all these experiments were initiated at the onset of flowering on 29 November.

The effects of three flower removal treatments were compared with untreated controls: (i) all flowers were removed for the first 14 days after flowering began, (ii) all flowers were removed for the first 28 days after flowering began, and (iii) flowers were removed from alternate nodes throughout the whole period of flowering.

The defoliation treatments involved the removal at the time flowering began of one leaf out of every four (25%), every alternate leaf (50%) and three leaves out of every four (75%); new leaves which appeared thereafter were removed in appropriate manner at weekly intervals until the plants matured.

For the shading treatments, white cotton cloth was held horizontally about 30 cm above the crop canopy throughout the reproductive phase, supported on a framework of wires attached to bamboo stakes at the corners of the plots. There was free circulation of air beneath the shades and the maximum and minimum temperatures were no more than 2°C higher in the shaded than in the control plots. Two types of shade were used: thin cloth and thick cloth, which intercepted 50 and 80% of the photosynthetically active radiation, respectively (light measurements were made at noon).

Effects of converting double-podded to single-podded plants

The effect of removing one of the flowers from every double-flowered node on yield and components of yield was investigated in a split-plot design (four replications) with cultivars in the main plots and the control and the flower removal treatment in the sub-plots. The treatment involved cutting off one of the flowers from each double-flowered node; this was repeated every two to three days as new flowers appeared. This trial was sown 11 November 1975 (harvested 5 March 1976) with cvs JG-62, P-272, P-502 and P-436; the experiment was repeated the next year (sown on 9 November 1976, harvested 24 February 1977). The sub-plot sizes in the two years were 3 × 3 m and 4 × 1.5 m, respectively. At harvest, the numbers and weights of pods and seeds were recorded for the whole of each sub-plot (after discarding border rows).

The mean monthly temperatures and monthly rainfall at Hyderabad and Hissar in the 1976—1977 winter season are shown in Table I.

TABLE I

Monthly rainfall and mean maximum and minimum temperatures (°C) during the winter season of 1976—1977 at Hyderabad and Hissar, India

Month	Hyderabad			Hissar		
	Rainfall (mm)	Max. temp.	Min. temp.	Rainfall (mm)	Max. temp.	Min. temp.
October	1	33.5	17.6	0	34.6	16.7
November	30	30.1	17.6	0	29.1	9.8
December	0	28.7	15.3	2	22.1	3.5
January	0	29.1	11.3	15	20.4	4.1
February	0	31.0	16.3	0	23.2	4.6
March	0	35.5	20.2	8	32.4	10.8
April	2	37.1	23.7	4	36.4	18.6

EXPERIMENT AT HISSAR

We compared the expression of the double-podded character and the yield of the early cultivars JG-62, Pant G-118, Pant G-120 and the medium-duration cultivar Pant G-119, sown in a randomized block design (with four replications) on 31 October 1976 in 4.5 × 3 m plots. The early cultivars began to flower in the first week of January, and the medium cultivar on 1 February 1977. The trial was harvested on 14 April 1977.

EXPERIMENT AT DALANG

An investigation of the effect of removing one of the flowers from every double-flowered node on yield and yield components was carried out with cvs JG-62, P-505, P-502 and P-436 sown on 20 May 1975 and harvested on 28 September. The design and procedure in this experiment was as described above for the similar experiments at Hyderabad. The sub-plot size was 3 × 2.4 m.

RESULTS

Distribution of double-podded nodes

In all locations where we have studied this character, two pods per node were generally found only on the earlier-formed, more proximal pod-bearing nodes. The later-formed, more distal nodes were generally single-podded.

Expression of the double-podded character in different cultivars at Hyderabad and Hissar

Cultivars did not differ significantly in expression of the double-podded character, either at Hyderabad or Hissar (Table II). At Hyderabad a much higher percentage of pod-bearing nodes was double-podded than at Hissar, although the absolute number of double-podded nodes was almost the same at both locations. The percentage differed because more single-podded nodes per plant were formed at Hissar, where the growing season was longer and yield levels higher. In these trials, the mean yields were 938 and 3520 kg ha^{-1} at Hyderabad and Hissar, respectively.

At Hyderabad, cv. JG-62 planted at different dates had a similar number of double-podded nodes per plant, but with the later planting, fewer single-podded nodes were produced and consequently the percentage of double-

TABLE II

Expression of the double-podded character in chickpea cultivars grown at Hyderabad and Hissar in 1976—1977

Cultivar	Nodes per plant		Double-podded nodes as percentage of all pod-bearing nodes	Yield (g/m^{-2})
	Double-podded	Single-podded		
Hyderabad				
JG-62	7.6	8.3	48	96
P-272	7.8	9.3	46	91
P-502	7.6	7.0	52	95
P-436	7.1	7.0	50	87
Pant G-120	7.0	6.7	51	99
SE mean	0.41	0.69	2.1	2.7
Hissar				
JG-62	6.3	54.9	10	356
Pant G-118	6.4	57.3	10	353
Pant G-119	7.3	63.3	10	326
Pant G-120	10.1	56.6	15	374
SE mean	1.42	9.45	1.9	15.1

podded nodes was higher (compare data for controls in Table IV with Table II).

Effect of population density

When cvs JG-62 and P-436 were grown at a range of plant populations, there was no significant difference between the two cultivars in the expression of the double-podded character, nor was there significant interaction between cultivars and plant population. The mean values in Table III show that there was also no significant effect of plant population on the percentage of pod-bearing nodes which were double-podded.

TABLE III

Effect of plant population on the number and percentage of double-podded nodes per plant (means for cvs JG-62 and P-436 grown at Hyderabad in 1976—1977)

Plant population (plants m^{-2})	Nodes per plant		Double-podded nodes as percentage of all pod-bearing nodes
	Double-podded	Single-podded	
8	19.3	23.9	45
21	10.4	11.9	47
33	6.8	7.0	49
50	6.0	6.0	50
75	5.1	5.4	49
100	4.8	5.3	48
SE mean	0.94	1.19	1.9

Effects of flower removal

The removal of flowers from alternate nodes throughout the reproductive phase had no significant effect on the percentage of pod-bearing nodes with two pods per node (Table IV). However, flower removal for the first 14 days after flowering began led to a striking reduction in the number and percentage of double-podded nodes, and flower removal for 28 days had an even greater effect (Table IV). These treatments tended to reduce the yield but the reductions were not significant at $P = 0.05$. The plants compensated for the reduction in total pod number per plant brought about by the flower removal treatments by producing heavier seeds and/or more seeds per pod.

TABLE IV

Effect of flower-removal, defoliation, and shading treatments on the number and percentage of double-podded nodes per plant of cv. JG-62 grown at Hyderabad in 1975—1976

Treatment	Nodes per plant		Double-podded nodes as percentage of all pod-bearing nodes	Yield ($g\ m^{-2}$)
	Double-podded	Single-podded		
Flower removal				
Control	6.2	13.5	31.5	112
Flower removal from alternate nodes	4.3	12.7	25.2	86
All flowers removed for 14 days	1.9	15.1	11.1	92
All flowers removed for 28 days	0.6	15.1	3.8	89
SE mean	0.47	2.13	2.60	7.9
Defoliation				
Control	5.2	14.8	26.0	126
25% defoliation	4.1	15.0	21.5	100
50% defoliation	2.6	11.9	17.9	79
75% defoliation	1.3	10.7	10.8	55
SE mean	0.26	0.86	1.00	5.4
Shading				
Control	4.7	12.1	28.0	117
50% shading	4.9	11.3	30.3	125
80% shading	2.8	9.0	23.7	80
SE mean	0.57	0.72	2.92	9.5

Effects of defoliation

Defoliation of more than 25% resulted in significant reductions in the numbers of double- and single-podded nodes per plant, but there was a relatively greater reduction in the number of double-podded nodes. The percentage of double-podded nodes and the yield were significantly reduced roughly in proportion to the degree of defoliation (Table IV).

Effects of shading

Neither thin nor thick shades significantly affected the percentage of double-podded nodes. Yield was reduced by 32% by the thick shades, but 50% shading had no yield-reducing effect. We have found that this treatment results in increased yields under some circumstances, probably because it protects the plants from heat stress by reducing the radiation load (Sheldrake and Saxena, 1978).

Effects of converting 'double-podded' plants to 'single-podded' plants

At Dalang only 6% of the pod-bearing nodes were double-podded. There was no significant effect on yield or components of yield of cutting off one of the flowers at every double-flowered node. Means for all four cultivars are shown in Table V. There were no significant interactions between cultivars and treatments in this experiment or in the experiments at Hyderabad.

At Hyderabad in 1975—1976 and 1976—1977 the yield was reduced by 10% and 6%, respectively as a result of converting 'double-podded' plants to 'single-podded' plants (Table V). These reductions were significant at $P = 0.05$. The pod number per unit area was significantly reduced by 22 and 15%, respectively. The plants were able to partially compensate for the reductions in pod numbers by increases in the number of seeds per pod and the weight per seed. The mean percentage of pod-bearing nodes with double pods in the control plots was 33 in 1975—1976 and 42 in 1976—1977.

DISCUSSION

Under all the conditions in which we studied the expression of the double-podded character, two flowers were formed at the majority of the flowering nodes. A high proportion of single-flowered nodes was observed only towards the end of the flowering period when the plants were senescing and few new pods were being set. The expression of the double-podded character

TABLE V

The effects on yield and yield components of cutting off one of the flowers from every doubl flowered node of 'double-podded' chickpea cultivars

Treatment	Yield ($g\ m^{-2}$)	Pod number m^{-2}	Seeds per pod	100-seed weight (g)
Dalang (1975)				
'Double-podded' (control)	78	1237	1.02	6.3
'Single-podded'	74	1130	1.02	6.5
SE mean	2.4	40.9	0.063	0.18
Hyderabad (1975—1976)				
'Double-podded' (control)	109	935	0.98	12.1
'Single-podded'	99	727	1.06	12.8
SE mean	1.5	16.3	0.017	0.26
Hyderabad (1976—1977)				
'Double-podded' (control)	108	792	1.03	13.3
'Single-podded'	102	672	1.10	13.8
SE mean	1.9	9.7	0.005	0.13

did not appear to be limited by the number of flowers per node, but rather by the process of pod-setting; at most of the single-podded nodes, one of the flowers aborted. By contrast, in peas (*Pisum sativum* L.) variation in the number of pods per raceme may be more influenced by environmental effects on the frequency of formation of single- and double-flowered nodes (Milbourne and Hardwick, 1968; Hole and Hardwick, 1976).

Similar numbers of double-podded nodes per plant were formed at Hissar and in the early and late sown plants at Hyderabad (Tables II and IV), but the percentages of double-podded nodes were 11, 28, and 49, respectively, owing to the subsequent formation of more or fewer single-podded nodes per plant. These differences were related to the length of the reproductive phase, which was longest in Hissar and shortest for the late-sown plants at Hyderabad; chickpeas senesce and mature when the weather rapidly becomes hotter and drier in February to March at Hyderabad, and in March to April at Hissar (Sheldrake and Saxena, 1978).

The simplest explanation for the formation of two pods per node only at the earlier-formed nodes would be in terms of an inhibition of the formation of a second pod at later-formed nodes by competition for photo-assimilates or other nutrients by the earlier-formed pods. The reductions in the number and percentage of double-podded nodes brought about by defoliation treatments (Table IV) would support this interpretation. But the lack of significant effect on the percentage of double-podded nodes by shades which cut out 80% of the light and reduced the yield by 32% (Table IV) does not agree with a simple assimilate-supply hypothesis; nor do the results of the experiment in which the onset of pod-setting was delayed by flower-removal for the first two or four weeks of the reproductive phase (Table IV). The large reduction in the number and percentage of double-podded nodes brought about by the latter treatment cannot be explained by the delay of the onset of the pod-setting into a set of environmental conditions unfavourable for the production of double-podded nodes, because no such suppression was observed in plants of the same cultivar planted five weeks later, which began setting pods under the same environmental conditions (Table II).

This evidence suggests that the setting of two pods per node is influenced by physiological changes which occur in the plant after the onset of flowering but which are not necessarily connected with pod development: some time after the beginning of flowering, the setting of two pods per node seems to be inhibited, whether or not pod development is taking place. This response may also be influenced by environmental conditions, such as temperature. At Hissar, the low temperatures during January and February (Table I) resulted in flower abortion and consequently pod-setting did not begin until about six weeks after the early cultivars began to flower; if this suppression had been equivalent to that brought about by flower removal at Hyderabad (Table IV) formation of the double-podded nodes should have been almost completely inhibited, but this was not the case (Table II).

Whatever the factors which control the expression of this character, there was a much higher percentage of double-podded nodes in Hyderabad than in Hissar. Some of the best-yielding cultivars which have been developed in peninsular India are double-podded. The experiments involving the conversion of double- to single-podded plants by the removal of one of the flowers from every double-flowered node indicate that, at Hyderabad, the double-podded plants had a yield advantage over the single-podded plants of 6 to 11% (Table V). At Dalang, the same type of experiment showed that the double-podded plants had no advantage in yield, which is not surprising since the double-podded character was poorly expressed; however, this result provides a useful contrast with the results from Hyderabad, because it indicates that the removal of one of the flowers from every double-flowered node did not result in reduced yield simply as a consequence of flower removal.

CONCLUSIONS

We conclude firstly that these results indicate that the double-podded character can confer a small but significant advantage in yield under conditions in which it is well-expressed, and secondly that this character may be of value in breeding for higher yield-potential under such conditions. To the first of these conclusions we have to add the qualification that it is based on the assumptions that our experimental conversion of double-flowered nodes to single-flowered nodes was roughly equivalent to the effects of the gene or genes which control flower number, and that the gene or genes which enable two flowers per node to be produced have no significant pleiotropic effects. The second conclusion has the limitation that it is based on studies with only a few cultivars; it is possible that against a different 'genetic background' the double-podded character may be of either less or more value than in the cultivars we investigated.

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