EFFECT OF PP333 AND TIBA GROWTH REGULATORS ON DEVELOPMENT AND YIELD COMPONENTS OF SPRING SOWN FIELD BEANS (*VICIA FABA* L.)

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ABSTRACT

A field experiment in 1982/83 investigated the effect of the foliar applied growth regulators TIBA and PP333 on spring-sown field beans (*Vicia faba* L.) grown at populations of 50, 70 and 90 plants/m². The chemical treatment changed plant growth habit and yield components.

Grain yield was increased significantly by PP333 and TIBA to 316 and 320 g/m² respectively, compared with 289 g/m² from the control. The increased yield was associated with significant increases in pods per plant and seed per unit area. Seed number was increased more by PP333 than by TIBA at 950 and 904 seed/m² respectively compared with the control at 821 seed/m². Both growth regulators may increase pod retention on the plants and PP333 increased harvest index.

Plants treated with PP333 were shorter and were less susceptible to lodging, while plants sprayed with TIBA were taller and lodged more than the control or the PP333 treated plants.

***Additional Keywords:** plant growth regulators, plant population, lodging*

INTRODUCTION

Spring sowing of field beans (*Vicia faba* L.) is now usual on New Zealand farms mainly because of the short growing period required. However, yield is less than from autumn-sown crops mainly because plants produce pods at fewer nodes (Newton, 1980). It seems that poor flower and fruit set and their premature abscission limit yield. These factors are greatly affected by environmental conditions (Newton, 1980) and by growth regulators (Addiscott and Lynch, 1951; Chattergee and Leopold, 1969). The foliar application of plant growth regulators such as kinetin, IAA and GA_3 to field beans has increased yield by significantly increasing pod set as a consequence of controlling flower and pod shedding (Abou-Elleil and El-Wazeri, 1978).

Lodging which sometimes occurs in tall plants with thin stems (Newton, 1980) can limit yield and make harvesting difficult. In addition, reductions in plant height would be useful for farmers by providing easy access for sprinkler irrigation and for inspection during later stages of crop growth. The growth regulator PP333 was first evaluated in 1980 as a growth retardant to reduce lodging and secondary vegetative tillering and to increase grain yield in perennial ryegrass (Hebblethwaite *et al.,* 1982). TIBA (2,3,5-Triiodobenzoic acid) anti-auxin has increased yield of soybean by inhibiting the apical dominance reducing plant height and by inducing a triangular-shaped canopy with a more vertical leaf orientation (Dhillon *et al.,* 1981). Foliar application of TIBA on *Vicia faba* at the first bud stage modified vegetative and reproductive growth; shortened internodes; reduced apical dominance; increased pod set on lower nodes and gave earlier seed maturity (Newaz and Lawes, 1980). Higher sowing densities produce taller plants with fewer branches (Pandey, 1981) which may make field beans more susceptible to lodging. In unlodged plants, the yield per plant is decreased but this can be partially compensated for by higher plant number per unit area (Seitzer and Evans, 1973).

This study was conducted to investigate the effect PP333 and TIBA on spring-sown field beans that were established at three plant populations. The aim was to demonstrate that plant growth regulator-induced changes in plant morphology and their interaction with plant population could lead to useful changes in pod production and retention and thus increase seed yield.

MATERIALS AND METHODS

Vicia faba cv. Maris Bead was sown on 14 September 1982 into a Templeton silt loam in plots 1.5 m wide by 30 m long with rows 15 cm apart using a Stanhay precision seeder. A factorial 3 x 3 x 2 randomised block design with three replicates was used. The treatments were three plant populations, (50, 70 and 90 plants/m²); three chemical treatments (control, TIBA and PP333) at two times of application (6 leaf stage and at commencement of flowering).

The seeds were treated with Benlate (50% a.i.) and Rothocide at 50 and 80 g/100 kg beans for control of *Ascochyta fabae*. Flowmaster superphosphate at 250 kg/ha was applied to the trial area prior to sowing. Simazine at 1.3 kg a.i./ha was used in a pre-emergence application for weed control.

For further control of *Ascochyta fabae* after emergence, the crop was sprayed with Chlorothalonil at 1.5 litres with 190 litres water/ha on 15 November 1982 and 21 January 1983. Black bean aphid (*Aphis fabae*) was controlled by spraying with premicarb at 125 g a.i./ha on 18 November. Plots were irrigated with 50 mm of water on 12 October, 23 November and 11 January 1983 when the soil moisture deficit had reached about 80 mm at each irrigation.

At the 6 leaf stage, (10 November 1982), plots to be treated were sprayed with 100 g a.i. /ha of TIBA or 1 kg a.i./ha of PP333, using a CO_2 - pressurised plot sprayer delivering 250 ℓ/ha. Application of the chemicals at the same rates was carried out at commencement of flowering, (9-10 node stages) on 27 November to plots as required by the design.

At two weekly intervals throughout the growth of the crop, two 0.25 m² sub-samples were taken from the middle 6 rows of each plot and five plants were selected at random for growth analysis. Sampling commenced on 3 November 1982 and continued until 25 January 1983.

A final sampling was taken on 7 February and at this harvest, four 0.25 m² quadrats were taken from each plot and 30 plants selected for determination of yield components. On 25 February, 9 m² from each plot was harvested using an experimental plot harvester.

RESULTS

The weather during the 1982/83 growing season was warmer than the long term average in November but about the same as the long term average in the other months of the experiment. Rainfall was lower than usual in September and January but was higher than average in October and in December (Table 1; Fig. 1). On 19 January, the trial area was hit by a severe hail storm and this led to considerable destruction of leaves, premature pod shedding and lodging of stems.

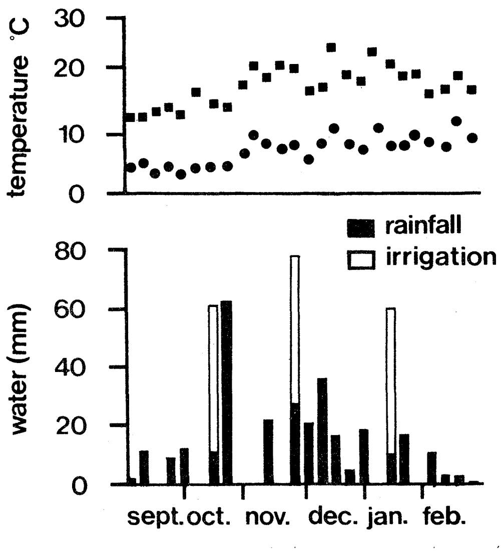

Figure 1: Mean weekly maximum (■) and minimum (●) temperature and total weekly rainfall, and irrigation applied during the growing season.

TABLE 1: Climate data for Lincoln College September 1982 to January 1983, compared with long term average in parentheses.

Month	Mean air temp. (°C)	Vapour pressure deficit (T KPa)	Solar radiation (MJ/m²/d)	Wind run (Km/d)	Rainfall (mm)
Sept.	8.6)	0.18	13.9	252	20.8
	(9.4)		(11.8)		(51)
Oct.	9.9	0.37	17.5	298	87.6
	(11.7)		(17.0)		(51)
Nov.	15.0	0.71	22.4	361	52.2
	(13.6)		(20.5)		(51)
Dec.	13.7	0.45	22.2	256	94.2
	(15.4)		(22.5)		(61)
Jan.	15.7	0.66	22.4	312	30.8
	(16.4)		(20.6)		(56)

Plant Height and Lodging

Plant height increased with increased stand density until the commencement of pod set which was related to an increase in internode length. Plant height was reduced signficantly by PP333 compared with the control and TIBA. This reduction was associated with a marked shortening in internode length in plants which had been treated with PP333 (Fig. 2). These plants were also more resistant to lodging (Table 2).

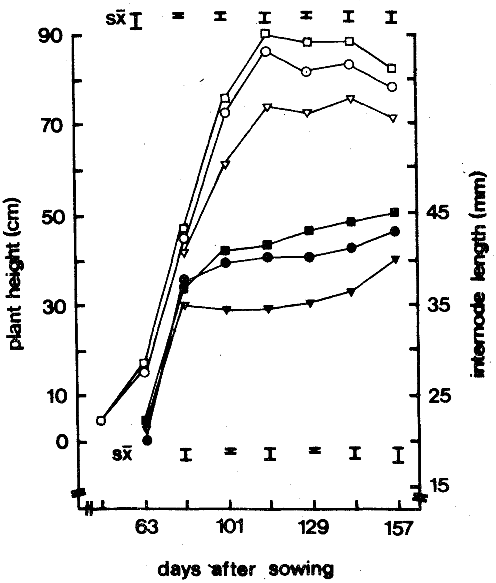

Figure 2: Effect of PP333 (▲), TIBA (■) and control (●) on plant height (open symbols) and internode length (closed symbols).

TABLE 2: Effect of plant population, PP333 and TIBA on lodging, yield and harvest index of spring-sown field beans. (GR = Growth Regulators; P = Plant Population).

Treatment	Plants/m² at harvest	Broken stems/m²	Seeds/m²	Seed yield g/m²	Harvest Index%
Population (plants/m²)					
50	46	24.6	923	310	47.1
70	71	21.0	903	312	47.0
90	78	22.9	848	302	45.7
Significant trends					
Linear	**	N.S.	N.S.	N.S.	N.S.
Quadratic	**	N.S.	N.S.	N.S.	N.S.
Growth regulators					
Control	64	24.5	821	289	45.4
TIBA	63	29.2	904	320	44.8
PP333	68	14.7	950	316	49.6
Significant designed contrasts					
Growth regulators vs control	N.S.	N.S.	**	*	*
TIBA vs PP333	N.S.	**	N.S.	N.S.	**
Significant interactions	N.S.	N.S.	N.S.	PxGR*	N.S.
$S\bar{x}$	2	2.8	29	10	0.7
C.V.%	9.9	52.2	14.0	13.4	6.5

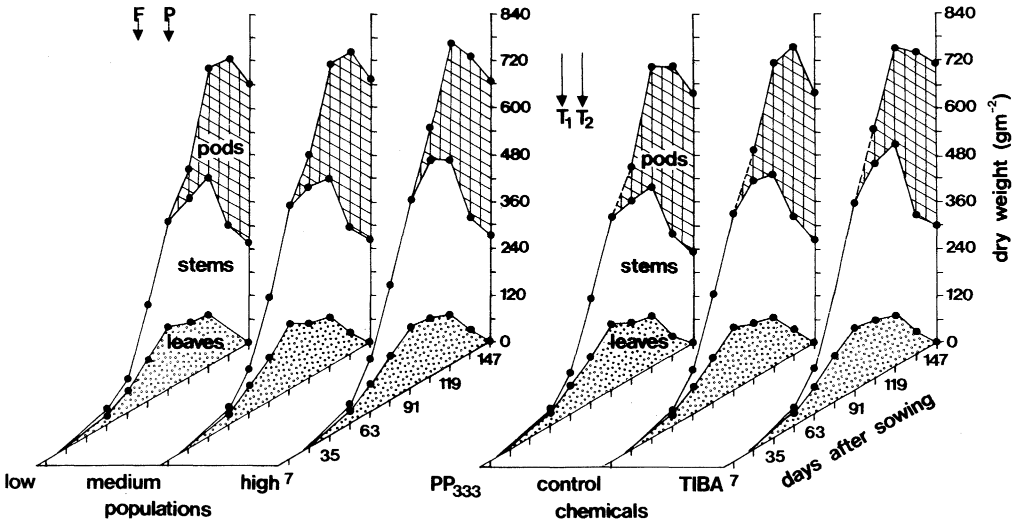

Figure 3: Pattern of dry matter accumulation and the distribution for the three populations and the control, TIBA and PP333 during the growing season. Where F = beginning of flowering; P = pod set; T1, T2 = first and second time of application.

Dry matter accumulation and partitioning

The pattern of dry matter accumulation in the plants over time in response to plant population and to the growth regulator is shown in Fig. 3. Leaf dry matter as a proportion of the total increased with increasing plant population up to 77 days after sowing. Stem dry matter also increased with population up to 119 days from sowing at 50 and 70 plants/m² and for a further two weeks at 90 plants/m² (Fig. 3). The applied growth regulators did not have any effect on the proportion of dry matter in leaves. However, PP333 reduced stem growth from 77 days after sowing to final harvest. Maximum dry matter was reached earlier in plants which had been treated with the growth regulators which may have indicated earlier maturity. Plants treated with TIBA reached maximum dry matter at 119 days after sowing and produced more dry matter than other treatments at the final harvest (Fig. 3).

Seed yield and components of yield

The different plant populations all gave a similar yield per unit area at 302-312 g/m² (Table 2) although yield per plant fell from 6.9 to 4.2 g/plant as population increased ($P \leqslant 0.01$) (Table 3). Both TIBA and PP333 significantly ($P \leqslant 0.05$) increased yield per unit area from 289 g/m² in the control to 320 g/m² for TIBA and 316 g/m² for PP333 (Table 2). This was due to an increase in number of pods per plant ($P \leqslant 0.05$) from 5.2 in the control in 5.6 with both TIBA and PP333. The growth regulators had no effect on seed yield per plant, seeds per pod or mean seed weight (Table 3). There was a significant linear ($P \leqslant 0.05$) increase in mean seed weight as population increased (Table 3).

The harvest indices of the plants were modified by the growth regulators, mainly by PP333 which increased it from 45.5% in the control to 49.6%. TIBA slightly reduced harvest index (44.8%) and the comparison between the two chemicals was highly significant ($P \leqslant 0.01$), (Table 2). There was a trend for harvest index to fall as population increased but this was not significant.

The mean header yield was 2.75 t/ha compared with the equivalent of 3.08 t/ha from the hand harvested samples, indicating a fair measure of comparability.

There were significant interactions between plant populations and growth regulators for lodging and for yield per unit area. Lodging increased from 12.8 to 17.0 plants/m² with increased populations in control plots. With the two growth regulators, maximum lodging with TIBA was 20.7 plants/m² at a population of 70 plants/m² while with PP333 the maximum was 15.8 plants/m² at a population of 90 plants/m² ($P \leqslant 0.01$) (Table 4).

With growth regulators, the highest yields were with 50 and 90 plants/m², at 325 and 318 g/m² respectively while in the control plots, these populations gave the lowest yields, with the maximum of 317 g/m² at 70 plants/m² (Table 5).

TABLE 4: Interaction of growth regulators and plant population on number of broken stems/m².

Population	Broken stems/m² TIBA	PP333
50	13.7	7.4
70	20.7	6.7
90	18.0	15.8
$S\bar{x}$	2.4	

DISCUSSION

The weather in Canterbury in 1982/83 was favourable for plant growth and the mean yield (308 g/m²) was high in comparison with the 142 g/m² achieved by Hill *et al.* (1977) and the 296 g/m² by Newton (1980). The rainfall during December was very high which would have reduced moisture stress during pod filling while on the debit side, the hail storm on 19 January certainly reduced final yield.

The different populations did not show any difference in yield per unit area (Tables 2 and 5) and this could be attributed to plasticity of the plant. Therefore, the increase in yield per plant at low density compensated for the reduction in plant number (Tables 2 and 3) (Seitzer and

TABLE 3: Effect of plant population, PP333 and TIBA on yield components of spring-sown field beans. (GR = Growth Regulators; P = Plant Population).

Treatment	Seed yield/ plant (g)	Pods/ plant	Seeds/ pod	Mean seed weight (mg)
Population (plants/m²)				
50	6.9	7.1	2.9	336
70	5.1	5.1	2.9	352
90	4.2	4.2	2.9	356
Significant trends				
Linear	**	**	N.S.	*
Quadratic	*	**	N.S.	N.S.
Growth regulators				
Control	5.2	5.2	2.8	352
TIBA	5.5	5.6	2.8	355
PP333	5.6	5.6	3.0	338
Significant designed contrasts				
Growth regulators vs control	N.S.	*	N.S.	N.S.
TIBA vs PP333	N.S.	N.S.	N.S.	N.S.
Significant interactions	N.S.	N.S.	N.S.	PxGR*
$S\bar{x}$	0.2	0.2	0.1	7
C.V.%	14.5	12.9	11.2	8.0

Evans, 1973). It has been previously reported that there is a high degree of growth plasticity in field beans over a range of plant populations (El-Saeed, 1968).

The principal component in determining yield is pod number per plant while other components are resistant to changes in plant population (Hodgson and Blackman, 1956; Newton and Hill, 1977). Change in the yield per plant in this experiment was characterised mainly by differences in pod number although seed weight was significantly different, (Table 3).

Pod set was reduced in plants at high density (Table 3) and this may be attributed to flower and pod loss when photosynthetic supply was restricted due to increased self-shading and earlier leaf loss (Weber, 1968). Soil fertility is also reported to have an effect on reduction in pod number at high densities of field beans (Soper, 1952). This can partially be related to the fact that high densities decreased nodule activity as reflected in competition for environmental factors such as water (Sprent and Bradford, 1977). It was also suggested that the effect of crowding in suppressing the initial branching of field beans could be associated with reduced nitrogen fixation (Hodgson and Blackman, 1956). High density increased plant height which might restrict movement of bees (Newton and Hill, 1977) as bees continued to pollinate the row of fertile flowers, rather than cross the space between rows (Bond and Hawkins, 1967) and this may decrease the number of fertile pods carried to maturity. Therefore, the higher yield per plant at low population may be due to more branches, pod formation on more nodes and increases in the number of pods per node (Newton, 1979). As plants at low populations produce more branches and pods per plant, it is possible that the reduction in mean seed weight may be a result of intra-plant competition for assimilates (Herbert, 1977). The mean seed weight from branches is often lower than that from the main-stem in an indeterminate species (Perry, 1975). Although Hodgson and Blackman (1956) and Newton (1979) found that plant population had little effect upon individual seed weight, this experiment shows a clear linear relationship between the two factors (Table 3). However, the favourable weather conditions during the experiment (Table 1, Fig. 1), especially during seed filling, may have increased photosynthetic productivity and reduced the competition for assimilates, although this was not tested.

TABLE 5: Interaction of growth regulators vs control on plant population in determining yield.

Population (plants/m^2)	Seed yield (g/m^2) Control	Growth regulators
50	280	325
70	317	310
90	270	318
$S\bar{x}$	17	

The growth regulators significantly increased seed yield per unit area ($P < 0.05$) by increasing pod number per plant while other yield components remained constant (Tables 2 and 3). While seed yield per plant was increased with growth regulators (Table 3), the differences were not large. As the pod numbers were similar up to the point of pod maturity, it seems that the growth regulators may prevent the shedding of some immature pods. It would appear that PP333 provided some protection against lodging although the extent to which this and the increased lodging in TIBA treatments affected pod retention and seed yield was not assessed (Table 4). These conclusions on pod number per plant are supported, especially for TIBA, by the results of Boize (1982) who found that the application of TIBA on soyabean (*Glycine max.* L.) increased the number of pods retained on plants at harvest. Shedding of flowers and immature pods is associated with relatively high auxin levels (Leopold and Thimann, 1949; Fisher and Loomis, 1954). TIBA may reduce pod abscission by lowering the level of endogenous ethylene which is believed to be responsible for the initiation of abscission (Freytag and Coleman, 1973). Hume *et al.* (1972) examined the effects of the environment before and after flowering on the response of soya beans to TIBA and found that yield increases were obtained only when rainfall and temperature were conducive to rapid vegetative growth. Thus the response to TIBA may have been associated with the favourable conditions during the season.

Although PP333 produced less dry matter as a result of its shorter stems (Fig. 3), it yielded more seeds than TIBA while mean seed weight was similar (Table 3). This indicates that PP333 can change the partition of assimilates in favour of the seed fraction. This was also indicated by its marked effect on harvest index which was increased from 45.5% in the controls to 49.6% following treatment with PP333. The harvest index of the control was similar to the value of 45.7% reported by Newton (1980). The significant difference in harvest index between the chemicals and the control was mainly due to PP333 as TIBA actually had a lower mean harvest index than the control at 44.8% and was itself very significantly different from the PP333 treated plants (Table 2). This result is no doubt associated with the greater height of the TIBA treated plants compared to those treated with PP333. It is possible that the reduction in stem length in PP333 treated plants at the beginning of pod set increased the competitive ability of the pods for assimilates and aided seed set and pod retention. Hodgson and Blackman (1957) reported that pod abscission in field beans was decreased when competition for assimilates has decreased by removal of upper reproductive nodes or by shading of the shoot apex. Gibberellic acid promotes shoot growth rate and tends to be concentrated in the most rapidly developing regions of plants (Jones and Phillips, 1966). Treatments of growth retardants which may affect gibberellin biosynthesis and metabolism and consequently reduce endogenous gibberellin levels may operate on shoot activity. PP333 may be an anti-GA_3 (Shearing and Batch, 1982) that alters the distribution of dry matter from stem to ear in perennial ryegrass where it increased seed yield and harvest index by significantly increasing the number of seeds harvested per unit area (Hebblethwaite *et al.,* 1982). A similar response by field beans to PP333-directed assimilate partitioning could account for the increase in yield. This specific developmental manipulation by PP333 plus the high rainfall during the growing season may have improved the response to PP333.

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