EFFECT OF BROAD BEAN MOTTLE VIRUS INFECTION ON THE GROWTH AND YIELD OF FABA BEAN

(*Vicia faba.* L)

By

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DEDICATION

To my family with love

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ABSTRACT

The effects of broad bean mottle virus (BBMV) infection on the growth, nodulation and yield of faba bean cultivars and lines were studied in Shambat during 2002/2003 growing season under green house conditions. All the components studied were consistently reduced by BBMV infection in comparison with healthy plants.

In the green house experiment, BBMV infection reduced the nodulation by 40.9%, the flowers number by 7 to 69.0% the number of pods as between 65 to 71% and the stem height by 16 to 42%.

The field surveys showed reduction of number of pods by 60 to 68%, number of seeds/pod by 62%, the weight of 100 seeds by 66% and the fresh and dry weight by 43 and 25%, respectively.

When the above data were subjected to statistical analysis, most of the parameters studied were significantly reduced by BBMV infection. Moreover, the present work revealed a significant difference in the response of the newly produced faba bean lines to faba bean infection. Further work on these lines is needed to recommend the BBMV resistance among the high yielding cultivars. Further research areas have been suggested.

ملخص الأطروحة

أجريت هذه الدراسة بكلية الزراعة شمبات في الموسم الزراعي 2002 – 2003 لدراسة تأثير الإصابة بفيروس تبرقش الفول المصري Broad bean mottle virus علي نبات الفول المصري. وقد شملت الدراسة تأثير الإصابة علي كل عناصر النمو، الإزهار، القرون، البذور (وزنها وعددها)، العقد البكتيرية بالإضافة إلى الوزن الجاف والرطب للمجموع الخضري. وقد دلت نتائج الدراسة علي أن الإصابة بهذا الفيروس تقلل جميع العناصر التي تمت دراستها في النباتات المصابة مقارنة بالنباتات السليمة.

دلت التجربة التي أجريت في الصوبة الزجاجية أن الإصابة بهذا الفيروس أدت إلى نقص الوزن الرطب والجاف للمجموع الخضري بنسبة 43 و25% وطول النبات 16 – 42%وعدد الأزهار بنسبة 7 – 69% وعدد القرون 65 – 71% والعقد البكتيرية بنسبة 9ر40%. أوضح المسح الحقلي نقصان في عدد القرون بنسبة 60 – 68% وعدد البذور في القرون 62% ووزن البذور 66% علي التوالي.

أظهرت التحاليل الإحصائية أن الإصابة بهذا الفيروس تحدث فروقات معنوية علي معظم العناصر التي تمت دراستها مما يوضح الأثر الضار للإصابة بهذا الفيروس وما يؤكد أهمية مكافحته وتطوير الدراسة في هذا المجال لانتاج سلالات مقاومة للمرض.

CHAPTER ONE

INTRODUCTION

Faba bean (*vicia faba* L.) is an important food grain legume in the Sudan, belonging to the family Leguminosae, and known by many names as faba bean, broad bean, horse bean and field bean but the first name has been widely used. It is grown in the temperate and subtropical regions and in south and west Asia. The origin of the crop is still debatable (DUC, 1997). In the Sudan it is grown as an exclusively irrigated winter crop in the Northern and in the River Nile States, it is considered the main source of proteins, carbohydrates and fibers (Eltinay *et al.*, 1993), thus it is used as human food for the middle and low income group of people in the developing countries, mainly Africa and Asia. It is also used as animal feed in Europe. Moreover, this crop plays an important role in agriculture due to it's ability of fixing atmospheric nitrogen (El Sheikh, 1993).

The crop is the main source of income among annually produced crops. Data on the average yield and areas sown with faba bean have indicated an increasing trend and considerable production expansion (Ahmed, 1996).

However, the production of this crop in the Sudan is facing many pests and diseases problems. Among these pests are the cowpea Aphid (*Aphis craccivora*) (*Koch*) and the larvae of the lesser army worms *Spodoptera exigua* (laphygma) (Ahmed and Eisa, 1991). Besides the damage caused by these pests, they are also vectors of some viral diseases. Faba bean in Sudan is also affected by several diseases such as powdery mildews, viral diseases, Root Rot and wilt (Claude *et al*. 1984).

Among the disease problems, the virus diseases are considered the most important ones. These diseases include: bean leaf roll virus, cucumber mosaic virus (Ahmed and Mills, 1984), broad bean mottle virus and bean yellow mosaic virus (Bos, 1980; Makkouk *et al.,* 1988) of these viruses, broad bean mottle virus and bean yellow mosaic virus are the most prevailing virus diseases in the Sudan (Ahmed and Hussein, 1989). Hence the present work was initiated:

1- To survey the incidence of broad bean mottle virus in the faba bean cultivars grown in Shambat fields.

2- To throw some light on the influence of B BMV on the growth, nodulation and yield components of faba bean.

3- To test the resistance and/or susceptibility of several faba bean lines to Broad bean mottle infection.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical background:

Broad bean mottle virus was observed for the first time in Nottinghamshire in England by Bawden *et al.* (1951) in a severely infected broad bean crop, it was later reported from a crop in Cambridge (Tinsly, 1957). Ford *et al.* (1981) also reported it from China. Borges and Louro, (1974) reported it in Portugal. In the Sudan it was first reported by Murant *et al.* (1974) and Hussein (1979).

2.2 Viron morphology:

Broad bean mottle virus has isometric particles about 26 nm in Diameter (David, 1985). The Sudanese strain was found to be 30 nm in Diameter (Murant *et al.*, 1974).

2.3 Host range and symptomology:

The host range of BBMV includes several species in the families Amaranthaceae, Chenopodiaceae, Solanaceae and Leguminosae. (Thornberry, 1966; Lane, 1974, 1981). The leguminosae has the biggest share of the host range to BBMV and it is suggested that the virus should be regarded as a food legume virus rather than solely of faba bean virus (Fortass, M. and Diallo, S. 1993). The host range of BBMV under experimental condition includes *Phaseolus vulgaris, Pisum sativum, Trifolium incarnatum, T. subterraneum, T. hybridum, T. repens, V. faba, Glycine soja, Lathyrus odoratus, Melilotus albus, M. officinalis, comphrena globosa, Chenopodium amaranticolor, C. album, C. guinloa, Lupinus albus, Medicago lupulina, Nicotiana clevelandii* (Bawden *et al.* 1951; Wetter *et al.*, 1960; Walter and Surin, 1973). The symptoms induced by BBMV on some of these species are shown in Table 1.

Table 1: Symptoms induced by BBMV on five plant species.

Host plants	Symptoms
Vicia faba	Systemic blotchy mottle
Nicotina clevelandii	Mild mottle
Phaseolus vulgaris cv canadian wonder	Chlorotic local lesion; systemic mottle and vein yellowing
Chenopodium amaranticolor	Chlorotic local lesions
Cyamposis tetragonobola	Necrotic local lesions or streaks

(Thornberry, 1996 and Lane, 1974, 1981).

In the Sudan BBMV induced systemic mottle on faba bean, it could be symptomless carrier or show symptoms similar to those of bean yellow mosaic virus (Hussein, 1979).

2.4 Transmission:

Broad bean mottle virus is transmitted to several species of leguminous plants by mechanical inoculation of sap (Bawden *et al.*, 1951), or by *Aphis craccivora* (*Koch*) as reported in the Sudan by Abu Salih (1973). It is also known to be seed transmitted when infecting the plants alone (Fortass and Bos, 1992) or when it occurred in a complex infection with bean yellow mosaic virus (Murant *et al.* 1974).

Successful insect transmission of BBMV was achieved using three chrysomelid beetles (Walter and Surin 1973) and two weevil species *Apion vovax* and *A. Arrogans* (Cockbain1983; Makkouk and Kumari, 1989), but non of these beetles and weevils were reported infesting field grown faba bean in Sudan (Siddig, 1982). Ahmed and Eisa (1991) proved significant transmission of BBMV by the larvae of the army worm *Spodoptera exigua* (Laphygma) in the field early in the season.

In Morocco, BBMV was transmitted by the curculionid weevils *Apion radiolus, Hypera variabilis, H. postica, Pachgtychius strumarius, smicronyx cyaneus* and *Sitona lineatus*, the later appeared an efficient vector as acquisition and inoculation occurred at the first bite. The rate of transmission was C.41% and virus retention lasted for at least 7 days (Fortass, and Diallo, 1993).

2.5 Physical properties of BBMV

Bawden and his co-workers (1951) reported that the thermal inactivation point of BBMV as is 95^{o}C and the longevity *in vitro* at 15^{o}C was less than 20 days. The dilution end point 100^{-3}.

2.6 Relation with plant cells and tissues:

Rubio and Slogteren (1956) reported X-bodies of broad bean mottle virus in *vicia faba* in the chlorotic areas of infected leaves as small granular at first and then become large and vacuolated. They attributed this variation in size to stage of formation. Makkouk and Kumari (1996) reported that BBMV spread systematically in all tissues of diseased plants.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Green house experiment:

The green house experiment was conducted in the winter of 2002/2003 in an insect-free green house of the Botanic garden of the Faculty of Agriculture. The green house was regularly sprayed with folimate insecticide to ensure insect control.

Leaf samples showing typical BBMV symptoms were collected from Shambat Demonstration Farm (University of Khartoum, Faculty of Agriculture) these leaves were used for the mechanical inoculation of the faba bean seedlings. The virus stock was regularly transferred to young plants at seven days interval to ensure a high indigenous virus titer.

3.1.1 The inoculation procedure:

The faba bean plants were grown in bags of about 20 inches diameter each containing a mixture of 2:1 silt and sand, respectively. Seed rate was 10 seeds/bag and then thinned to 5 plants/bag.

Eight lines of broad bean were used throughout this study. Plants of each line were inoculated with broad bean mottle virus while similar numbers of plants were left as control. Each line was tested in a separate experiment using a completely Randomized Design (CRD) with four replications.

Infection was achieved by sap inoculation throughout this study. All plants inoculated when young. The plants were inoculated when they were 15 days old comparable plants serving as control were maintained without inoculation in the same compartment in the green house.

The infective leaves tissues were homogenized with mortar and pestles containing cold 0.05 M. Phosphate Buffer, pH 7.0 (1 ml Buffer per 1 gram leave tissues). The crude sap was then strained through a piece of absorbent cotton, carborundum (600-mesh) was dusted on the upper surfaces of the leaves before applying the inoculum.

The inoculations were performed by dipping the forefinger in the inoculum and then rubbing it on the previously carborundum – dusted upper surfaces of young fully expanded leaves. The inoculated leaves were rinsed with distilled water shortly after inoculation to remove excess inoculum so as to avoid toxicity.

3.1.2 The evaluation of BBMV infection on some yield components of faba bean plants:

The height of the stem was recorded weekly to study the effects of the BBMV infection on stem height (it was measured at soil surface). At the onset of flowering the flower numbers per plant were recorded, and later as the plants approached maturity indicated by the yellowing and drying of pods, the number of pods were determined. The plants were dug from the soil and the roots were washed carefully with water and the number of nodules was recorded.

3.2 The field surveys:

Field surveys were conducted in Shambat area to determine the disease incidence.

3.2.1 Field observations:

Three fields were visited every week and surveyed during the growing season 2002/2003.

Disease incidence was determined on the basis of visual symptoms. Five locations in each field were chosen randomly, ten plants showing BBMV symptoms were randomly selected and tagged. For each selected infected plant, an adjacent apparently healthy plant was tagged for comparison, plants chosen as healthy and later developed symptoms were discarded. At maturity the infected and healthy tagged plants were harvested separately. For each plant the number of pods, number of seeds and the weight of 100 seeds were determined. Then these plants were cut about two inches above the soil level, placed in paper bags, weighted for the fresh weight and then kept in an oven for 48 hours at 80^oC and the dry weight was determined using the Mettler P_3 sensitive balance. Comparison was then made between the infected and apparently healthy plants using student's t-test.

CHAPTER FOUR

RESULTS

4.1 The green house experiment:

4.1.1 Number of flowers:

The results of the green house experiment showed that the BBMV infection induced reduction of number of flowers by 49, 7 and 69% in the first, second and the third week, respectively (Table 2).

Statistical analysis showed highly significant differences between infected and healthy plants (Appendix 1).

Statistical analysis of the lines also showed highly significant differences among the lines in the number of flowers in the first, second as well as the third week. Line P_7, P_1 and P_8 produced the highest number of flowers in the first, second and third week respectively. The least number of flowers was produced by line P_4. Statistical analysis for interaction showed significant differences in the first and the third week but no significant difference was obtained in the second week (Appendix 1).

Table 2: Effect of BBMV on the flowers number.

Line	1st week			2nd week			3rd week		
	Inf	Non	Mean	Inf	Non	Mean	Inf	Non	Mean
P_1	bc 1.35	cd 1.45	bc 1.40	12.8	14.6	a 13.7	de 0.90	ab 2.55	a 1.73
P_2	e 0.6	bc 1.70	bc 1.15	12.4	12.8	a 12.6	ef 0.75	c 1.98	bc 1.37
P_3	e 0.45	c 1.65	c 1.05	11.1	11.0	ab 11.0	ef 0.65	c 1.95	c 1.30
P_4	e 0.35	cd 1.55	c 0.95	9.0	10.4	b 9.7	ef 0.55	bc 2.30	bc 1.43
P_5	e 0.60	b 1.75	bc 1.18	11.6	12.8	a 12.2	f 0.35	bc 2.20	c 1.28
P_6	de 0.85	ab 2.35	b 1.60	12.1	12.5	ab 12.3	e 0.70	b 2.50	ab 1.60
P_7	cd 1.50	a 2.65	a 2.08	10.9	12.0	ab 11.5	d 1.25	bc 2.30	a 1.78
P_8	bc 1.70	cd 1.40	b 1.55	13.2	13.8	a 13.5	ef 0.65	a 2.90	a 1.78
Mean	b 0.93	a 1.81		a 11.6	a 12.5		b 0.73	a 2.34	

4.1.2 Number of pods:

As shown in Table 3, BBMV induced 65,70 and 71% reduction in the number of pods in the first, second and the third week, respectively. This reduction was highly significant. Line P_3 produced more pods in the third week, fewer number of pods were produced by line P_4, P_2 and P_5 in the first, second and the third week, respectively (Figure 1). Statistical analysis showed a highly significant difference between both lines and interaction between lines and infection (Appendix 2).

4.1.3 Stem height:

BBMV infection induced greenish to yellow systemic mosaic and leaf crinkling (Plate 1) the severe symptoms developed in leaf necrosis and leaf distortion, which resulted in reduced inter-nodes and stunting (Plates 2 and 3). The reductions of stem height due to infection were 24, 19,15 and 16% for the first, second, third and fourth week, respectively (Table 4), but statistically not significant (Figure 2). Statistically significant differences between lines were obtained in the first week only. No statistically significant differences in the interaction were obtained during the four weeks (Appendix 3).

Table 3: Effects of BBMV on the pods number.

Line	1st week			2nd week			3rd week		
	Inf	Non	Mean	Inf	Non	Mean	Inf	Non	Mean
P_1	f 0.90	c 2.60	c 1.75	d 1.15	c 2.10	bcd 1.63	e 1.00	d 1.90	bcd 1.45
P_2	f 0.53	b 3.30	cd 1.42	e 0.50	c 2.00	e 1.25	f 0.40	cd 2.00	d 1.20
P_3	f 1.0	a 5.40	a 3.20	d 1.10	a 5.10	a 3.10	f 0.40	bcd 2.30	cd 1.35
P_4	f 0.5	de 1.75	d 1.13	de 0.75	c 2.10	de 1.43	ef 0.75	ab 2.50	abc 1.63
P_5	f 0.55	c 2.60	cd 1.58	e 0.45	b 2.60	cde 1.53	f 0.35	bcd 2.05	cd 1.20
P_6	c 2.55	c 2.60	b 2.58	d 1.05	b 2.75	b 1.90	ef 0.85	a 2.80	a 1.83
P_7	ef 1.15	c 2.50	c 1.83	d 1.15	bc 2.40	bc 1.78	e 1.10	abc 2.45	ab 1.78
P_8	f 0.70	cd 2.15	cd 1.43	e 0.45	b 2.75	bcd 1.60	ef 0.70	a 2.90	a 1.80
Mean	b 0.99	a 2.86		b 0.83	a 2.73		b 0.69	a 2.36	

Fig (1) . Effect Of BBMV Infection On the Average Number Of Pods Formed

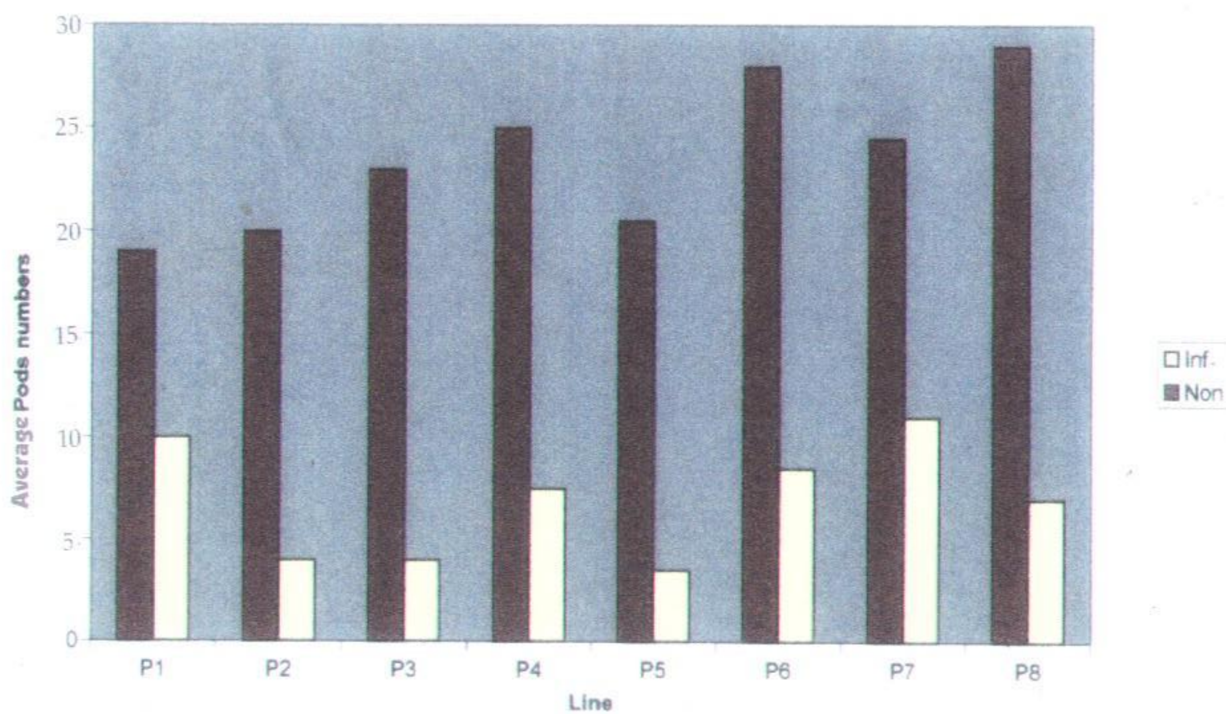

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Plate 1 Faba bean infected with BBMV

A B

A : Infected
B : Healthy

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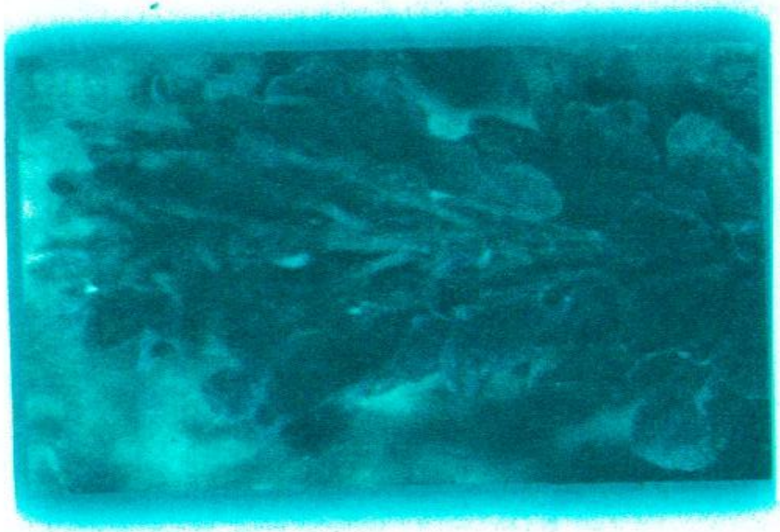
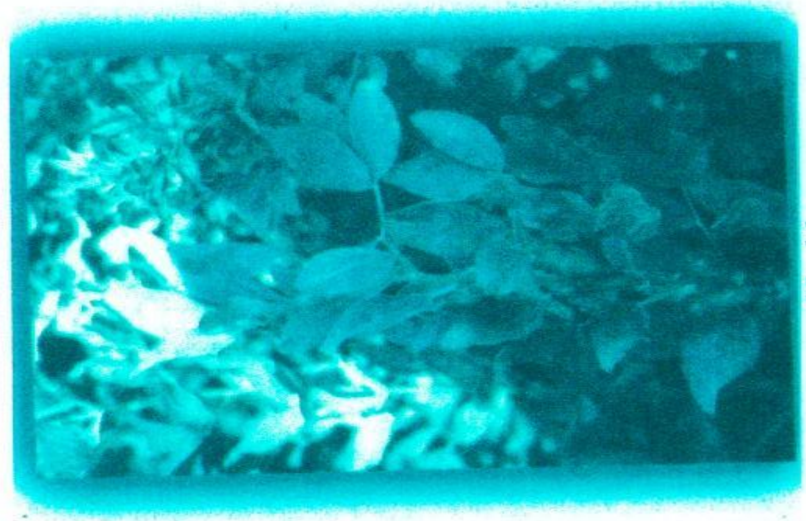
Plates 2 and 3 Faba bean infected with BBMV



Infected



Healthy 24

Table 4: Effects of BBMV on stem height (cm).

Lines	1st week			2nd week			3rd week			4th week		
	Inf	Non	Mean	Inf	Non	Mean	Inf.	Non	Mean	Inf.	Non	Mean
P_1	24.3	31.9	b 28.1	20.2	25.0	a 22.6	27.3	34.4	a 30.9	30.6	36.5	a 33.6
P_2	23.8	27.1	ab 25.5	17.9	23.2	a 20.6	26.8	30.1	a 28.5	30.3	33.5	a 31.9
P_3	21.2	32.6	ab 26.9	23.3	28.3	a 25.8	28.9	33.8	a 31.4	30.7	37.0	a 33.9
P_4	24.4	33.1	a 28.8	21.0	26.0	a 23.5	28.4	36.1	a 32.3	28.3	31.5	a 29.9
P_5	24.7	31.2	a 28.0	18.3	23.3	a 20.6	28.1	33.6	a 30.9	28.9	35.8	32.4
P_6	25.7	31.9	a 28.8	19.5	24.5	a 22.0	38.9	35.0	a 37.0	33.7	39.8	a 36.8
P_7	19.5	26.8	b 23.2	22.5	26.8	a 24.7	23.9	33.3	a 28.6	27.5	36.2	a 31.9
P_8	21.1	26.8	B 23.9	26.0	30.3	A 28.2	24.2	29.8	A 27.0	27.9	32.6	A 30.3
Mean	B 23.1	A 30.2		A 21.1	B 25.9		B 28.3	A 33.3		B 29.7	A 35.4	

Fig (2) Effect Of BBMV Infection On Average Of Stem Hight

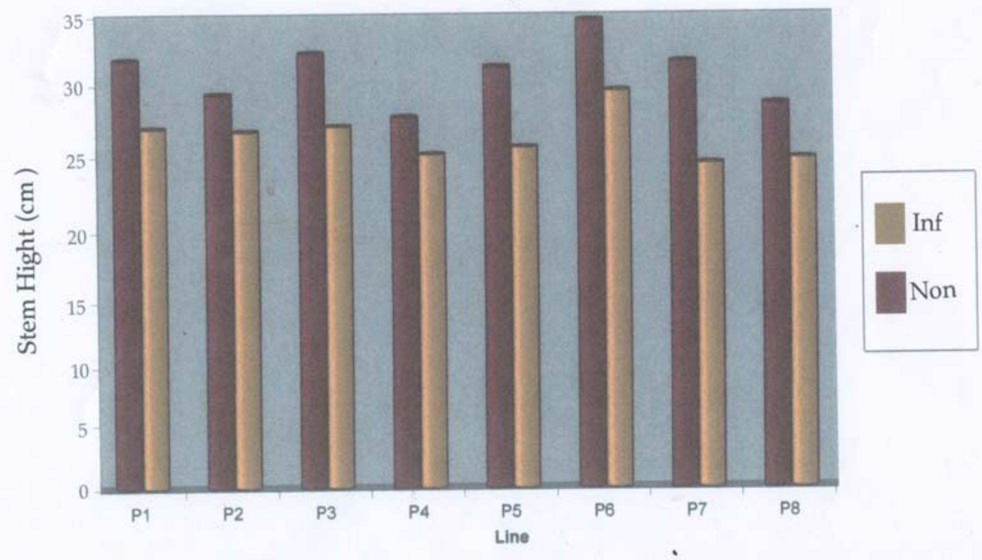
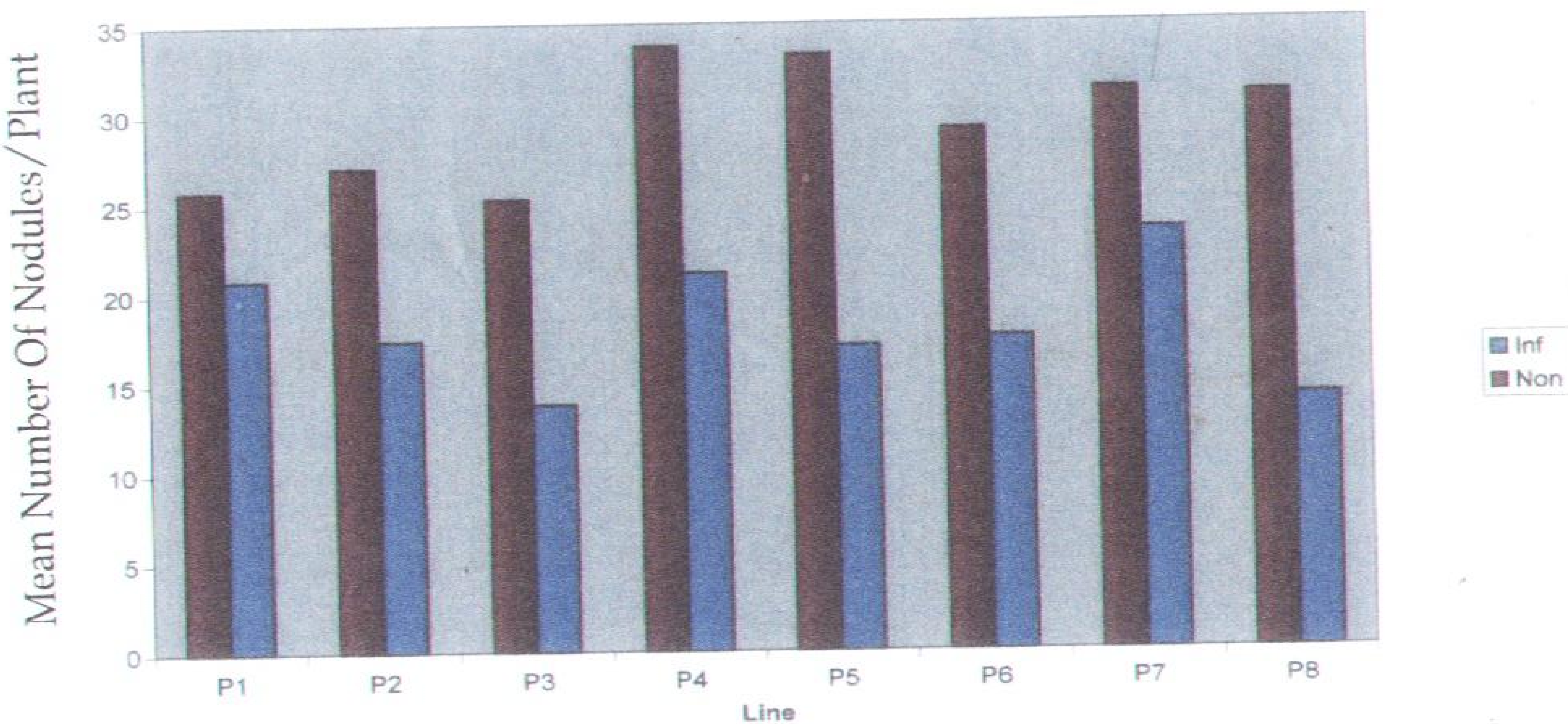


Fig (3) . Influnce of BBMV infetion on Nodulation



Lines $P_6 + P_4$, P_8 and P_6 are not affected very much by BBMV infection in the four weeks, while P_7, $P_2 + P_5$, P_8 and P_4 were so much affected by BBMV infection.

4.1.4 Nodulation:

As shown in Table (5) the nodulation was reduced by 40.9% and the reduction was significant. Line P_3 is affected very much by BBMV infection while line P_4 tolerated the infection (Figure 3). Statistical analysis showed a significant difference between the lines (Appendix 4).

4.2 The field surveys:

The surveys showed that the BBMV infection caused a considerable reduction in the yield and yield components of broad bean (Plate 4). The reduction of the number of pods was highly significant ranging from 60 up to 68%. The reduction of number of seeds per pod was highly significant as up to 62% reduction was obtained. Highly significant difference was obtained in the weight of 100 seeds as the reduction reached up to 66%. Moreover, the fresh and dry weights of shoots showed highly significant difference reaching 43 and 25% reduction, respectively (Table 6).

Table 5: Influence of BBMV on number of nodules

Treatment	Infection	Non	Mean
P_1	de 20.8	bcd 25.8	bc 23.3
P_2	ef 17.4	bc 27.1	bc 22.3
P_3	f 13.8	cd 25.3	c 19.6
P_4	de 21.1	a 33.8	a 27.5
P_5	ef 17.0	a 33.3	ab 25.2
P_6	ef 17.5	abc 29.1	bc 23.3
P_7	ef 17.0	ab 31.3	ab 24.7
P_8	f 14.1	ab 31.0	bc 22.6
Mean	b 17.5	a 29.6	
SEL ±	1.22^{++}		
SEI ±	0.61^{++}		
SE (L x I) ±	0.72^{++}		

Table 6: Effects of BBMV on yield components of broad bean

	No. of pods	No. of Seed/pod	Weight of 100 seed/g	Fresh weight/g	Dry weight/g
X	18.04	15.81	17.82	18.9	31.8
Y	56.12	42.07	51.90	32.9	42.3
SXY	$\pm$8.3	$\pm$1.85	$\pm$1.75	$\pm$3.72	$\pm$2.86
T.cal	4.59^{++}	14.2^{++}	19.457^{++}	3.766^{++}	3.671^{++}

Reduction =	68%	62%	66%	43%	25%
X	17.6				
Y	47.9				
SXY	$\pm$ 2.44				
t.cal	12.436^{++}				
Reduction	63%				
X	14.2				
Y	35.6				
SXY	$\pm$0.5				
T.cal	42.63^{++}				
Reduction	60%				

CHAPTER FIVE

DISCUSSIONS

The present results have clearly demonstrated the harmful effects of BBMV infection on the yield components of the faba bean cultivars and lines studied. The virus infection resulted in up to 25% reduction in the shoot dry weight. In similar studies, Hago (1991) reported that BBMV infection reduced the shoot dry weight of the faba bean cultivar Silaim by 74.4. Similarly, Makkouk (1987) found that BBMV infection caused 54% yield losses to faba bean. BBMV infection caused a significant reduction in the number of flowers. Hago (1991) also obtained similar results. One of the adverse impacts induced on faba bean by BBMV infection was the reduction in number of pods and seeds as the virus infection caused up to 71% reduction in the pod number, and up to 62% reduction in the seed number.

These results were in agreement with the results obtained by Hago (1991). Also, Hussein (1992) reported 38.5% and 43.5% reduction in the average number of pods and seed weight, respectively. The quality of seeds as indicated by 100 seed weight was also affected by up to 66% reduction in the seed weight. Such results are in agreement with those obtained by Hago (1991).

The complete inhibition of flowering and reduction in some lines may be due to the interaction of the virus with the flowering habit of the crop as a result of the severe reduction in plant size and lacking of energy available for flowering.

The effects on the final yield could generally be associated with the reduction exerted on the growth of the plant as a result of the virus infection. The reduced photosynthetic surface area resulted in less available energy for flowering and maturity and this may explain the observed reduction in the final yield as speculated by Tu *et al.* (1970).

There were variations in the response of the faba bean cultivars and lines to BBMV infection. These different responses could be attributed to the differences in the genetic factors and the symbiotic effectiveness of the *Rhizobium* spp.

It is worth mentioning that the severity of damage imposed on the nodulation is correlated fairly well with the virus damage on the growth of the plant as measured by it's fresh and dry weight. Stemming from this point, the reduction on the nodulation may be partially explained by the impeding of photosynthesis and translocation of photosynthates to the lower parts of the plant or may be due to the increased respiration rate of the infected plants. There by, restricting the energy available to the bacteria in the nodules. Since a considerable curling of leaves occurred, a high level of auxin contents accumulation in the leaves is suggested with a possible concomitant-reduced auxin translocation to the main stem and roots and this could result in the reduced nodule growth as speculated by Tu *et al.* (1970b).

Such reduction in the nodule growth due to imbalance of auxin and enzymes and/or reduction in photosynthesis and increased respiration has also been suggested by Bawden and Pirie (1952), Diener (1963), Bawden (1964) and Tu *et al.* (1968).

The fact remains that BBMV infection causes reduction in the nitrogen content and in the nodulation of the infected crop, and the nitrogen content resulting from the reduction in the nitrogen fixation.

Such conclusions are of great concern as this crop is superior in it's yield, protein content and ability to enrich the soil with nitrogen. It is highly recommended that precautions should be taken to prevent virus infection so as to avoid the drastic losses caused by BBMV infection. Further work should include screening and breeding for resistance to BBMV among the high yielding faba bean cultivars and/or lines.

REFERENCES

Abu Salih, H.S. (1973). Effect of sowing date on incidence of Sudanese broad bean mosaic virus in, and yield of *Vicia faba*. Ann. App. Biol. 74: 371 – 378.

Ahmed A.H. and Hussein, M.M. (1989). Plant pathology report on evaluation of the virus diseases of faba bean in the new areas and screening for resistance. Nile Valley Regional Programme 1988/1989 Annual Report, 14 pp.

Ahmed A.H.; Eisa, E.B. (1991). Transmission of broad bean mottle virus by the larvae of *Spodoptera exigua fabis newsletter*, 30 – 31.

Ahmed, A.H. and Mills, P.R. (1984). Host range and properties of cucumber mosaic virus (cmv-) infecting *Vicia faba* in Sudan. *Fabis newsletter*, 9: 31 – 32.

Ahmed, A.T. (1996). Production and improvement of cool season food legume in the Sudan.

Bawden, F.C. (1964). Plant viruses and virus diseases. Rolland Press Co., N.W. 361 p.

Bawden, F.C. and Pirie, N.W. (1952). Physiology of virus diseases. *Ann. Rev. Plant Physiol.* 13: 171 – 188.

Bawden, F.C.; Chaubhuri, R.P. and Kassanis-B, (1951). Some properties of broad bean mottle virus. *Ann. App. Biol.* 38: 774 – 784.

Borges, M.DE. Lourdes, V. and Louro, D. (1974). A biting insects as a vector of BBMV – Agronomia lusitiana.

Bos, L. (1980). Virus diseases of *Vicia faba* and some other crops in the Nile Valley (Sudan and Egypt) and the involvement of ICARDA. Consultant Report. ICARDA. Aleppo (1980) 15 pp.

Claude, C.; Bernier, Salim B.; Hanounik, Mustafa, M.; Hussein, Hosni, A.M. (1984). Field manual of common faba bean diseases in the Nile valley. Information Bulletin No. 3. ICARDA.

Cockbain, A.J. (1983). Viruses and virus-like diseases of *Vicia faba* L. in the faba bean (*Vicia faba* L.), Cd. P. D. Hebblethwaite, 421 – 61. London, U.K. Butterworths.

David G.A. and Walkey (1985). Applied plant virology 15 – 16. Heinemann London.

Diener, T.O. (1963). Physiology of virus infected plants. *Ann. Rev. Phytopathology*, 1: 197 – 218.

Duc, G. (1997). Faba bean *vicia faba*. Field Crop Research 53: 99 – 109.

Elsheikh, E.A.E. (1993). Soil microbiology. Khartoum University Press.

Eltinay, A.H.; Mahgoub, S.O.; Mahgoub, S.A. and Daoud, O.H. (1993). Amino acid composition and proximate analysis of faba bean (*vicia faba* L.) seeds, U. of K. J. Agric. Sci. (1): 62 – 73.

Ford, R.E.; Bissonnette, H.L.; Horsfall, J.G.; Millar, R.L; Schleget, D.; Tweedy, B.G. and Weathers, L.G. (1981). Plant Pathology in China 1980. Plant Dis., 65: 706 – 714.

Fortass, M. and Boss, T. (1992). Broad bean mottle virus in Morocco, variability in interaction with food legume species and seed transmission in faba bean, pea and chickpea. Netherlands Journal of Plant Pathology 98: 6, 329 – 342.

Fortass, M.; Diallo, S. (1993). Broad bean mottle virus in Morocco, curculionid vectors and natural occurrence in food legumes other than faba bean (*Vicia faba* L.) Netherlands. Journal of Plant Pathology, 99: 4, 219 – 226.

Hago, G.A. (1991). Field investigations on the effect of bean yellow mossaic virus and broad bean mottle virus infection on the yield components of faba bean. M.Sc. Thesis, University of Khartoum.

Hussein, M.M. (1979). Recent research on certain broad bean disease in the Sudan fabis Newsletter, 1: p. 25.

Hussein, M.M. (1992). Studies of viruses in food legume in the Sudan. A paper presented at the Reg. Coor. Meeting NVRP. Khartoum, Sudan.

Lane, L.C. (1974). Adv. Virus Res. 19: 151.

Lane, L.C. (1981). In: Handbook of Pl. virus infection and comparative diagnosis, p. 333; Ed.E. Kurstak. Elsevier/North Holland Biomedical Press Amsterdam.

Makkouk, K.M. and Kumari, S.G. (1996). Detection of ten viruses by the tissue plot immuno-assay (TBIA). Arab Journal of Plant Protection, 14 (1), 3, p.

Makkouk, K.M. and Kaumari, S.G. (1989). Apion arrogans, aweevil vector of broad bean mottle virus fabis newsletter, 24: 26 – 27.

Makkouk, K.M. Bos, L.L., Azzam, O.I., Koumari, S.G. and Rizkalla (1988). Survey of virus affecting faba bean in six Arab countries. Arab Journal Pl. Prot. 6: 61.

Makkouk, K.M. (1987). Yield loss evaluation. ICARDA Annual Report 1987, p. 49.

Murant, A.F., Abu Salih, H.S. and Goold, R.A. (1974). Viruses from broad bean in the Sudan, in the annual report of the Scottish horticultural Research Institute (1973), p. 67 U.K.

Rubio, M., Van Slogteren, D.H.M. (1956). Light and electron microscopy of X-bodies associated with broad bean mottle virus, Phytopathology, 46: 401 – 402.

Siddig, S.A. (1982). Major pests of faba bean in the Sudan in faba bean improvement, ed. G. Hawtin and C. webb, 277 – 83. ICARDA – ISBN, 1982. Netherlands.

Thronberry, H.H. (1966). In: Index of plant virus diseases. U.S. Dep. Agric. Hdbk, No. 307, p. 235.

Tinsley, T.W. (1957). Virus diseases of leguminous Plants. Ann. Rep. Rothmasted exp. Stn.

Tu, J.C.; Ford, R.E. and Quiniones, S.S. (1970). Effects of soybean mosaic virus and/or bean pod mottle virus infection on soybean nodulation. Phytopathology 60: 518 – 523.

Tue, J.C., Ford, R.E. and Krass, C.J. (1968). Comparisons of chloroplasts and photosynthetic rates of plant infected and not infected by maize dwarf mosaic virus. Phytopathology, 58: 285 – 268.

Walter, H.J. and Surin, P. (1973). Transmission and host range studies of broad bean mottle virus. Plant Dis. Rep. 57: 833 – 836.

Wetter, C. Paul, H.L. Brandes, J. and Quantz, L. (1960). Z-Natur Forsch. B 15, 444.

Appendix 1: Number of flowers

1st week.

Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	29.1575	1.9438			
Lines	7	8.2875	1.1839	6.43++	2.25	3.12
Infection	1	16.4025	16.4025	89.05++	4.08	7.31
Line x infection	7	4.4675	0.6382	3.46++	2.25	3.12

Error	48	8.8400	0.1842			
Total	63	37.9975				

C.V: 30.1% SEa : ± 0.152
SEb: ± 0.076 SEab: ± 0.215

2nd week

Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	135.16	9.0107			
Lines	7	105.65	15.0929	4.87++	2.25	3.12
Infection	1	20.25	20.25	6.54+	4.08	7.31
Line x infection	7	9.26	1.3229	0.43 NS	2.25	3.12
Error	48	148.68	3.0975			
Total	63	283.84				

C.V: 14.43% SEa : ± 0.622
SEb: ± 0.34 SEab: ± 0.88

3rd week

Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	46.1661	3.0777			
Lines	7	2.2599	0.3657	5.54++	2.25	3.12
Infection	1	41.4414	41.44	627.9++	4.08	7.31
Line x infection	7	2.1648	0.3093	4.69	2.25	3.12
Error	48	3.1675	0.066			
Total	63	49.3336				

C.V: 16.79% SEa : ± 0.091
SEb: ± 0.045 SEab: ± 0.128

Appendix 2: Number of pods

1st week.

Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	102.2548	6.817			
Lines	7	22.7736	3.2534	17.73++	2.25	3.12
Infection	1	59.8689	59.8689	326.26++	4.08	7.31

Line x infection	7	19.6123	2.8018	15.27++	2.25	3.12
Error	48	8.8075	0.1835			
Total	63					

C.V: 22.67% SEa : ± 0.151
SEb: ± 0.076 SEab: ± 0.214

2nd week

Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	90.2994	6.02			
Lines	7	18.8144	2.6878	38.51++	2.25	3.12
Infection	1	58.1407	58.1407	832.96++	4.08	7.31
Line x infection	7	13.3443	1.9063	27.31++	2.25	3.12
Error	48	3.35	0.0698			
Total	63	93.6494				

C.V: 14.84% SEa : ± 0.093
SEb: ± 0.047 SEab: ± 0.132

3rd week

Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	48.5294	3.2353			
Lines	7	5.0344	0.7192	8.28++	2.25	3.12
Infection	1	41.2807	41.2807	475.04++	4.08	7.31
Line x infection	7	2.2143	0.3163	3.64++	2.25	3.12
Error	48	4.17	0.0869			
Total	63					

C.V: 19.65% SEa : ± 0.104
SEb: ± 0.052 SEab: ± 0.147

Appendix 3: Stem height (cm)

1st week
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Sov	d.f	SS	MS	F(c)	F.t

					5%	1%
Treatment	15	1023.2775	68.2185			
Lines	7	324.7875	46.3982	4.43++	2.25	3.12
Infection	1	663.0625	663.0625	63.34++	4.08	7.31
Line x infection	7	35.4275	5.0611	0.30NS	2.25	3.12
Error	48	502.44	10.4675			
Total	63	1525.7175				

C.V: 12.01% SEa : ± 1.14
SEb: ± 0.57 SEab: ± 1.62

2nd week

Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	754.0523	50.2702			
Lines	7	376.1611	53.7359	2.09NS	2.25	3.12
Infection	1	375.8751	375.8751	14.16++	4.08	7.31
Line x infection	7	2.0261	0.2894	0.01NS	2.25	3.12
Error	48	1234.6575	25.72201			
Total	63	1988.7098				

C.V: 21.58% SEa : ± 1.79
SEb: ± 0.90 SEab: ± 2.53

3st week
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Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	891.7125	59.4475			
Lines	7	190.4179	27.2025	1.96NS	2.25	3.12
Infection	1	645.16	645.16	46.60++	4.08	7.31
Line x infection	7	56.1346	8.0192	0.58NS	2.25	3.12
Error	48	664.5650	13.8451			
Total	63	1556.2775				

C.V: 12.37% SEa : ± 1.32
SEb: ± 0.66 SEab: ± 1.86

4st week

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Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	827.3294	55.1553			
Lines	7	269.5694	38.5099	1.43NS	2.25	3.12
Infection	1	508.5025	508.5025	18.91++	4.08	7.31
Line x infection	7	49.2575	7.0368	0.26NS	2.25	3.12
Error	48	1290.685	26.8893			
Total	63	2118.0144				

C.V: 15.94% SEa : ± 1.83
SEb: ± 0.92 SEab: ± 2.59

Appendix 4: Nodulation

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Sov	d.f	SS	MS	F(c)	F.t	
					5%	1%
Treatment	15	2849.3644	189.9576			
Lines	7	301.2619	43.0374	3.64++	2.25	3.12
Infection	1	2349.8257	2349.8257	198.75++	4.08	7.31
Line x infection	7	198.2768	28.3253	2.40+	2.25	3.12
Error	48	567.495	11.8228			
Total	63	3416.8594				

C.V: 14.63% SEa : ± 1.22
SEb: ± 0.61 SEab: ± 1.72

Abbreviations

BBMV	:	Broad bean mottle virus
Sov.	:	Source of variance
d.f.	:	Degree of freedom
SS	:	Summation of squares
MS	:	Means of squares
f.(c)	:	F-calculated
f.t	:	F-tabulated
C.V.	:	Coefficient of variance
SE	:	Standard error
SEa; SEL	:	Standard error for lines
SEb: SEI	:	Standard error for infection

SEab: SE (L x I): Standard error for lines and infection interaction

X	:	Average number of the infected plants
Y	:	Average number of the healthy plants