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The Effects of Sowing Date on Faba bean and *Orobanche crenata* Relationship

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ABSTRACT

Background: *Orobanche crenata* Forsk (O.c.) is an obligate root parasite that subsists on several important legume crops. Recently, it has become one of the major constraints limiting the productivity of broad bean in different parts of the world. **Methods:** four experiments were carried out to study the effects of some ecological factors on faba bean (*Vicia faba*) and O.c relations, quantitatively and qualitatively. **Results**: Generally, the results of the survey work and the four experiments indicated that when different host plants (faba bean cultivars) are parasitized by the same parasite (e.g. O.c), they evolved different responses. **Conclusion:** The scopes of inflicting damages to faba bean due to crenate broomrape are many and diverse, but the degree of attention and work done to solve the problems caused by the parasite is still very low.

Keywords: Faba bean , *Orobanche crenata,* broomrape.

1. Introduction

Faba bean (*Vicia faba* L.) belongs to the family Fabaceae, sub-family Papilionoidae, order Fabales (Cronquist, 1981). In addition it has a number of English names, such as broad bean, field bean, and horse's bean. It is commonly known in the Sudan as Egyptian bean (Foul masri) (Muehlbauer and Tullu, 1997; Mukhtar, 1998). Different Origins were reported for broad bean e.g. North America (Decandol, 1986), Asia (Cubero, 1974; Landizineky, 1975) and Egypt (Abdalla, 1979). The main producing countries of faba bean in the world are Ethiopia, Algeria, Morocco, Tunisia, Egypt, Sudan, Iraq, Afghanistan, China, India, France, Italy, U.S.A., Mexico, Brazil and Argentina (Bascure, 1993; Mukhtar, 1998). In 1981 it was grown on 3.6 million hectares in about 50 countries and the total production exceeded 4 million tons (Hawtin and Hebblethwail, 1983).In the Sudan, during the period of 1997-2001, the area planted with faba bean was 50,060 ha (AOAD, 2005). During the season 2001-2002 the crop was grown on 58,000 ha, with an average yield of about 2517 kg/ha (FAO, 2002). In 2004, faba bean cultivated area became 60480 ha, and the average yield was 2860 kg/ha (AOAD, 2005). Orobanchaceae are by far the largest family of parasitic plants with a large number of species but only a few are considered as important in leading to economic losses (Lambrada, 2008; Joel, 2009; Parker, 2009; Heide-Jorgensen, 2011). Crenate broomrape (Orobanche crenata Forskal) is a root holoparasite belonging to the family Orobanchaceae, which infects various dicot plants (Parker and Riches, 1993; Bennett and Mathews, 2006; Joel, 2009; Heide-Jorgensen, 2011). It causes the most widespread damage on cool-season food and forage legumes in northern Africa, southern Europe, and western Asia countries (Joel, 2009; Restuccia *et al.,* 2009), and also occurs sporadically on vegetables like carrot, eggplant, and tomato (Linke *et al.,* 1993; Dahan and El-Mourid, 2004; Matusova and Bouwmeester, 2005; Rubiales *et al.,* 2006; Lambrada, 2008).It is especially damaging faba bean, peas and lentils, and has seriously reduced areas planted to these crops mainly around the Mediterranean region and Middle East countries (Parker, 2002, 2009). Since its introduction in the northern part of Ethiopia in the 1980s, crenate broomrape parasitism on legume crops, especially on faba bean, has become increasingly important (Besufekad *et al.,* 1999; Abebe *et al.,* 2013). Faba bean cultivation is strongly hampered by the occurrence of the parasite, which threatens the livelihoods of many farmers (Besufekad *et al.,* 1999; Rezene and Kedir, 2006; Abebe *et al.,* 2013). Planting dates could be manipulated to minimize crenate

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broomrape infection, as environmental factors affect the germination and development of the parasite (Manschadi *et al.,* 2001). It is reported that shifting faba bean sowing from October to November and from December to January reduced the numbers and dry weight of attached and emerged broomrapes, both O. crenata and O. foetida (Grenz *et al.,* 2005). In late-sown crops, two factors are known to reduce parasite damage: decreasing seed germination due to suboptimal soil temperatures and obstructing seedling development during underground stages (Habimana *et al.,* 2014). Early planted faba bean was severely infected by crenate broomrape than the delayed sowing one in the Tach-Gaint district of the South Gondar zone (Kemal and Olivera, 2016). According to Manschadi et al. (2001), only in moderately infested plots, shifting of the planting time of faba bean result in a significant decrease in parasite dry weight and an increase in crop seed yield. Dense infection of crenate broomrape on faba bean tends to be associated with less fertile soils (Trabelsi *et al.,* 2017). In contrast, a high level of composted manure or nitrogen (N) fertilizer showed a suppressive effect on the parasite (FAO, 2008). Nutrient management can promote both resistance and tolerance to broomrape parasitism in crops at pre-attachment and also after establishment stages (Parker, 2009).

2. Methods

2.1 Location

The field work was carried out for two consecutive winter seasons during 2006/07 and 2007/08 at the Demonstration Farm of the Faculty of Agricultural Sciences, University of Dongola. The Demonstration Farm is situated on the Eastern bank of the main River Nile (Selaim), Northern State Sudan, within latitude 19°-10́N, and longitude 30°-29́E.

2.1.1 Climate

The climate of the area is described as a desert climate, which characterized by a very hot dry summer, and low temperature during winter. Temperatures range between 36.4̊C in May and 18.2̊C in January. Solar radiation is as high as 25.8 MJM, with mean bright sun shine duration of 10.5 hours. Rain fall with an annual mean of 1mm. The soil is desert type (Nahid, 2007) (Table 1).

a) Season 2006/2007

Month / Element	2006			2007			
	October	**November**	**December**	**January**	**February**	**March**	**April**
Temp °C M.max	39.8	30.1	26.0	25.1	29.9	34.9	40.2
M. min	23.4	13.8	9.0	8.1	10.9	15.3	20.8
Rainfall	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R.H%	22	28	35	35	26	19	15
Wind DIR	N	NNW	NNW	NW	NNW	N	N
SPEED CKNOTS	11	11	9	10	9	10	10

Sources Ministry of Science and Technology Metrological Authority Administration of Data Weather winter

Note:

Max=	Maximum	**Min=**	Minimum	**DIR=**	Direction
TR=	Trace	**N=**	North	**W=**	West
Knot=	1.85 Km/hr	= 0.5 m/s			
	1.15 mile/hr	= 1.69 feet/hr			

b) Season 2007/2008

Month	2007			2008			
Element	October	November	December	January	February	March	April
Temp °C M .max	39.7	34.5	29.3	25.5	27.7	36.9	39.9
M. min	23.1	17.5	12.1	10.2	10.0	17.1	27.1
Rainfall	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R.H%	20	24	31	31	29	19	15
Wind DIR	NNW	N	NNW	NW	NNW	N	N
SPEED CKNOTS	11	11	10	11	11	10	11

Sources Ministry of Science and Technology Metrological Authority Administration of Data Weather winter.

Note:

Max=	Maximum	**Min=**	Minimum	**DIR=**	Direction
TR=	Trace	**N=**	North	**W=**	West
Knot=	1.85 Km/hr	= 0.5 m/s			
	1.15 mile/hr	= 1.69 feet/hr			

2.1.2Soil properties

Samples of the soil of the experimental site were analyzed at Dongola Research Station to obtain the soil properties including EC, pH, $CaCO_3$ and proportion of soil texture (clay, silt, and sand).

2.1.3 Land preparation of the experimental site

The experimental site was disc ploughed followed by disc harrowing, leveled with leveler. Plot size was 4m×2m = 8m2 for experiment 1 and 2; 4m×3m = 12m2 for experiment 3. Each plot comprised 3 ridges with interrow space of 60 cm and interrow spacing of 20cm for experiment 1 and 2. For experiment 3, each plot comprised 4 ridges with interrow spacing 80 cm. and interrow spacing of 20cm plots and ridges were prepared manually. Irrigation water was pumped from the Nile.

2.1.4 Experimental seeds

Seeds of three faba bean cultivars were used in the project, namely Selaim (SL.M) Hudeiba 93 were obtained from Dongola Research Station and from Hudeiba Research Station respectively. Seeds of the third cultivar (The Turkish) were obtained from the local market. Seeds of Orobanche crenata were already available as seed bank in the selected experimental site. The selected site was condemned as sick plots.

2.2 Survey of the Parasite and its host

Several excursions were carried out to survey the occurrence and distribution of the parasite Orobanche crenata (O.c) and its host plant faba bean among the native plant communities of Dongola area. The study was performed during the period of December to March for two consecutive years (2006/07 and 2007/08). The study covered four sites from East of the Nile (Gartoude, Labab Island, Elbyara and Kasora from Selaim Basin), two sites from West of the Nile (Altaiti and Soari south of Dongola).

2.3 The experiment

Faba bean seeds were sown within 18 plots. Three sowing dates were used i.e., 20 October, 20 November, and 20 December. The selected site was condemned as sick plots (infested with O.c seeds). The treatments were arranged in a spilt-split plot design with the sowing date as the main plot, the cultivar as the sub plot, and continual removal or unremoval of O.c as the sub-sub plot with three replications for each treatment. Continual removal of O.c twice a week as (control); Orobanche left without removal until harvest as (infected). The recommended cultural practices were followed. Experimental plots were kept weed free except for Orobanche crenata. Spraying was done several times against different types of pests and microorganisms. Irrigation was practiced every 10 days on average. The harvest times for the three sowing dates were 20th February, 10th March and 15th March, respectively for both winter seasons of years 2006/07 and 2007/08.

2.3.1 The host and the parasite parameters measured

The host parameters: Plant height (cm) (Appendix 8), number of nodes per plant (Appendix 9), Number of tillers per plant (Appendix 10), dry weight of shoot (g)/m2 (Appendix 11), dry weight of root (g)/m2 (Appendix 12), number of seeds/m2(Appendix 13), 100 seeds weight (g) (Appendix 14). The parasite parameters were: number of O.c plants/m2 (Appendix 15), O.c dry weight of shoot O.c (g)/m2 (Appendix 16).

All the parameters were taken at harvest time.

2.3.1.1 Plant height (cm)

Nine plants were randomly selected from each plot (3 from each raw). Plant height was measured from the base of the plant (at the soil surface) to the end of the flag leaf. The mean plant heights for the selected plants were recorded.

2.3.1.2 Number of nodes/plant

From the nine plants selected randomly from each plot, number of nodes was counted. The mean numbers of nodes were recorded per plant.

2.3.1.3 Dry weight of shoot

From each plot, an area of 3 meter square was selected for harvest. The fresh weight of samples were air dried until constant weights were reached to obtain the dry weights. The mean weight per meter square was obtained.

2.3.1.4 Dry weight of root

Likewise, from the area of 3 meters square the root system were separated from the stems and weighed. Each fresh weight sample was air dried until constant weight was reached to obtain the dry weight of root system. The mean weight per meter square was obtained.

2.3.2 Statistical analysis

Statistical analysis of variance was conducted for all parameters measured, using SAS (1997).

3. Results

3.1 Soil Properties

Table 2: Soil properties of experimental site.

	EC	pH	CaCo3	CLAY%	SILT %	SAND%
	2.83	6.95	7.1	10	10	80
R_1	1.54	8.22	7.8	11	40	49
	1.67	7.84	6.7	9	11	80
	2.83	8.5	7.6	13	21	66
R_2	0.52	8.32	7.0	14	15	71
	0.56	8.1	6.2	8	17	75
	1.17	7.52	8.0	11	12	77
R_3	1.56	8.27	8.5	14	14	72
	0.61	7.36	7.8	13	19	68

Source: Dongola Research Station

3.2 The Experiment

The tested faba bean cultivars (Selaim, Hudeiba-93, the Turkish) under the studied three sowing dates (Sd1, Sd2, Sd3) in the two seasons (2006/07) and (2007/08) showed variations in growth habits (Appendix tables 1 to 7) (Figures 1.c and 1.d).

Fig 1.c: Effect of sowing dates on faba bean under the infection of *Orobanche crenata*

Fig. 1.d: Faba bean cultivars attacked by O.c

V1: Cultivar (Selaim) **V2:** Cultivar 2 (Hudaiba-93) **V3:** Cultivar 3 (Turkish Cultivar)

3.3 Plant height

Figure 1 depicts the effect of Orobanche crenata on the plant height of the faba bean cultivars under different sowing dates during the two seasons (2006/2007 and 2007/2008). The results of season I revealed that O.c had significant effect on the performance of plant height of faba bean cultivars in the studied three sowing dates, but the results showed variation within sowing dates 1 and 2; while no significant results were realized with sowing date 3.The results of the season 2 showed significance difference between the means of the three sowing dates. However, there was no significant difference between the results of each sowing date separately.

Fig 1.a: Afield of faba bean parasitized by O.c (Gartode village)

Fig 1.b: A field of faba bean free from O.c (Gartode village)

3.4. Number of nodes/plant:

The results of season 1 showed that O.c had significant effects on the performance of the number of nodes per plants at sowing dates 1 and 2, but it had no significant effect on the same trait at sowing date 3. In season 2, no significant differences were obtained between treatments means at sowing dates 1 and 3, while significant differences were shown between the treatments means at sowing date 2 (Fig. 2).

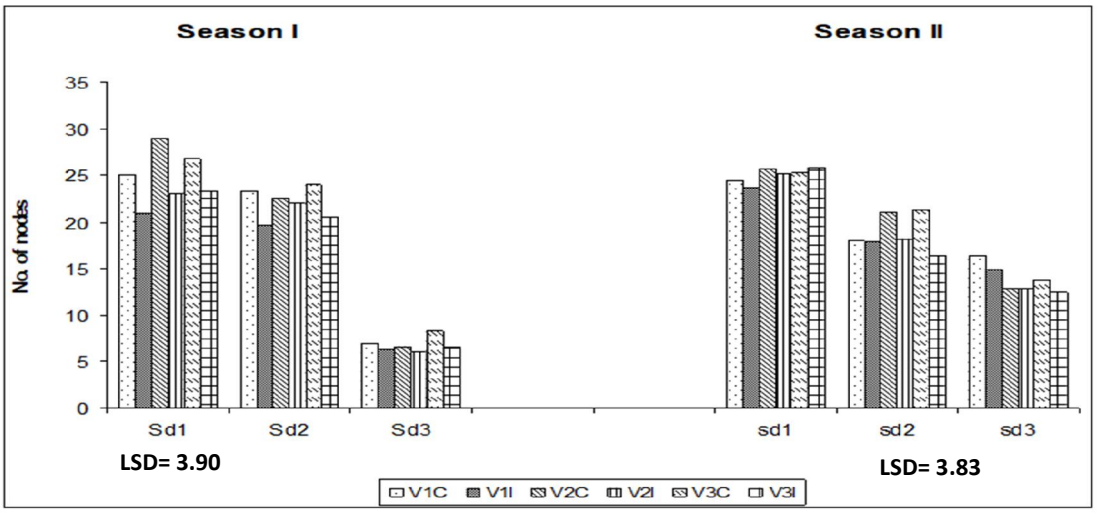

Fig. 2: Effect of sowing dates on the number of nodes of faba bean under the infection of *Orobanche crenata*.

Sd 1:	(Sowing date 1) (20/10)	**Sd 2:**	(Sowing date 2) (20/11)	**Sd 3:**	(Sowing date 3) (20/12)
V1C:	Cultivar1 (SL-M),control	**V2C:**	Cultivar2 (Hudeiba-93) control	**V3C:**	Cultivar3 (Turkey) control
V1I:	Cultivar1 (SL-M), infected	**V2I:**	Cultivar2 (Hudeiba-93) infected	**V3I:**	Cultivar3 (Turkey) infected

3.5. Number of tillers/plant

The results of season 1 showed that O.c had significant effects on the performance of the numbers of tillers per plant of faba bean at the studied three sowing dates, but the results showed variations within each sowing date. The results of season 2 showed significant difference between the three sowing dates and between treatments means of the sowing date 1 and 2, but showed no significant difference between treatments of sowing date 3 (Figure 3).

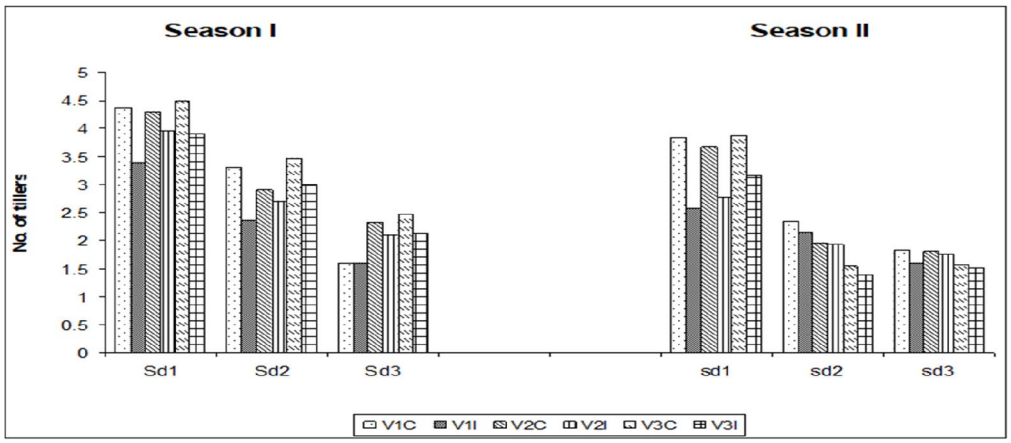

Fig. 3: Effect of sowing dates on the number of tillers of faba bean under the infection of Orobanche crenata.

Sd 1:	Sowing date 1 (20/10)	**Sd 2:**	Sowing date 2 (20/11)	**Sd 3:**	Sowing date 3 (20/12)
V1C:	Cultivar1 (SL-M),control	**V2C:**	Cultivar2 (Hudeiba-93) control	**V3C:**	Cultivar3 (Turkey) control
V1I:	Cultivar1 (SL-M), infected	**V2I:**	Cultivar2 (Hudeiba-93) infected	**V3I:**	Cultivar3 (Turkey) infected

3.6. Dry weight of shoot

The results of season 1 realized that O.c had significant effects on the performance of the dry weight of shoot of faba bean cultivars at sowing date 1 and 2, but showed no significant difference at sowing date 3. However, no significant differences were obtained between treatments of cultivar 1 at sowing

date 1. At season 2 there was no significance difference between treatments of cultivars 2 and 3; while there was significant difference between treatment of cultivar 1 at sowing date 1. However, significant differences were realized between treatments of all cultivars at sowing date 2, while no significant differences were realized between treatments of sowing date 3 (Fig. 4).

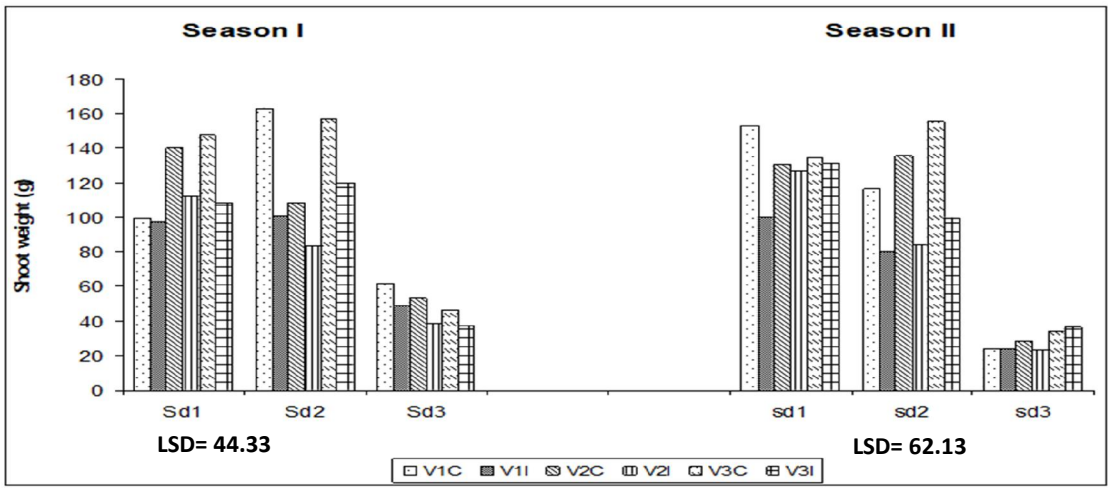

Fig. 4: Effect of sowing dates on the shoot weight of faba bean under the infection of *Orobanche crenata*.

Sd 1:	Sowing date 1 (20/10)	**Sd 2:**	Sowing date 2 (20/11)	**Sd 3:**	Sowing date 3 (20/12)
V1C:	Cultivar1 (SL-M),control	**V2C:**	Cultivar2 (Hudeiba-93) control	**V3C:**	Cultivar3 (Turkey) control
V1I:	Cultivar1 (SL-M), infected	**V2I:**	Cultivar2 (Hudeiba-93) infected	**V3I:**	Cultivar3 (Turkey) infected

3.7. Dry weight of root

The results of season 1 and season 2 realized that O.c had significant effects on the performance of the dry weight of root at the studied three sowing dates. However, the result of cultivar 1 at sowing date 1 and 3 of season 2 were inconsistent (Fig. 5).

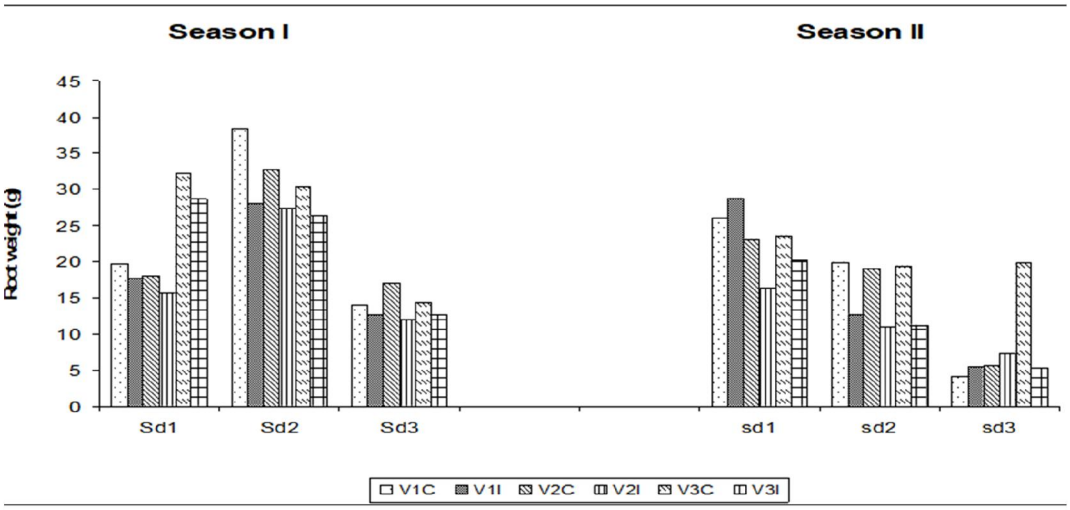

Fig. 5: Effect of sowing dates on the root weight of faba bean under the infection of *Orobanche crenata.*

Sd 1:	Sowing date 1 (20/10)	**Sd 2:**	Sowing date 2 (20/11)	**Sd 3:**	Sowing date 3 (20/12)
V1C:	Cultivar1 (SL-M),control	**V2C:**	Cultivar2 (Hudeiba-93) control	**V3C:**	Cultivar3 (Turkey) control
V1I:	Cultivar1 (SL-M), infected	**V2I:**	Cultivar2 (Hudeiba-93) infected	**V3I:**	Cultivar3 (Turkey) infected

4. Discussion

This experiment aimed to investigate some ways and means of alleviating the stress on yield performance of faba bean resulting from the Orabanche crenata attack. The different sowing dates (20/10, 20/11, and 20/12) were assumed to affect faba bean/Orabanche crenata relations. The present study showed that the tested cultivars of faba been varied significantly in their response to the parasitism of O.c. under different sowing dates. The growth and yield characters (plant height, number of nodes per plant, number of tillers per plant, dry weight of shoot, dry weight of root, number of seeds/m2 and 100 seeds weight/m2), generally, were significantly affected by O.c. under the tested three sowing dates. Sowing date 3 (20/12) was found to be the most affected one by the parasitism of O.c, followed by sowing date 2 (20/11), while sowing date 1 (20/10) was found to be the least affected one. The results also showed that V3 (the Turkish cultivar) was the most affected cultivar, followed by V2 (Hudaiba cultivar), while V1 (Selaim cultivar) was the least affected cultivar by O.c. The results obtained in this experiment were corroborated by the report of Hamdoun *et al.* (2008), who stated that the parasite O.c was introduced to the Northern State through the Turkish cultivar imported from Egypt in 2001/2002. Before 2001/2002 the Northern State was free from O.c. It has long been recognized that the infection of faba bean and other crops such as lentil and chickpea by O.c in the Mediterranean basin is profoundly influenced by the date of planting, depending on the region. In this study, it was noticed that delaying sowing date was found to reduce the yield of faba bean substantially. These results concur with those of Mersa-Garcia (1984) and Garcia Torres (1982) in Spain, Nassib *et al.* (1984) in Egypt and Raaimakers *et al.* (1988) in Syria. The results of the two seasons, 2006/2007 and 2007/2008 were not in harmony. Generally, the results of season 1 were consistent, while those of season 2 were erratic (inconsistent). The difference between the results of the two seasons may be attributed to the fluctuations of the climatic factors, especially the temperature during season 2, which affected the germination of Orobanche seeds and consequently its incidence in the fields of faba bean. So, if maximum yield is the strategy to be followed, October planting of faba bean may give the highest yield in the Northern State, with implementation of the optimum control methods of Orobanche. On the other hand, if reduction of O.c infestation is the strategy to be followed, delayed sowing date (e.g. December) may significantly reduce the O.c incidence. These results were in agreement with those of Ait Abdellah and Hamadeche (1996), who reported that the delayed sowing date significantly reduced O.c infestation in faba bean.

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