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Effect of Sowing Dates on Development of Basil Downy Mildew Caused by *Peronospora belbahrii* under Natural Field Conditions

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Two field experiments were conducted in 2016 and 2017 growing seasons under natural infection of basil downy mildew in the Experimental Farm of Sids Agricultural Research Station, Agric. Res. Center, Beni-Sweif governorate to examine the impact of sowing dates on basil downy mildew epidemic caused by *Peronospora belbahrii* and productivity of basil plant. Sweet basil seeds were sown in different dates, early date (February), mid date (March) and late date (April). In general, early sowing significantly gave lower disease incidence and severity than late sowing. Although the early sowing dates (February) gave the highest reduction in disease incidence and severity but drastically affected plant growth and yield to the lowest value. The highest efficacy was obtained when sweet basil seeds were sown in March 15th which significantly decreased the incidence and severity of downy mildew to an important level and consequently, increased fresh and dry yields of herb.

Keywords: *Downy mildew, Epidemic, Peronospora belbahrii, Sowing dates and Sweet basil.*

Sweet basil (*Ocimum basilicum* L., Fam. Lamiaceae) is the most economically important medicinal and aromatic herb crop used for both fresh and dry consumption and as a source of essential oil and oleoresin for manufacturing perfumes, food flavors (Simon *et al.*, 1990). Basil is an important source of antioxidants (Koroch *et al.*, 2010), antimicrobial agents (Elgayyar *et al.*, 2001 and Hussain *et al.*, 2008) with a potential use in food preservation (Suppakul *et al.*, 2003), insecticidal activities and recently it has found to have *in vivo* anti malaria activity (Zheljazkov *et al.*, 2008).

Recently, a new destructive disease of basil, downy mildew, caused by *P. belbahrii* Thines (Garibaldi *et al*., 2004; Belbahri *et al*., 2005 and Thines *et al*., 2009) that has spread rapidly and become epidemic in all basil growing areas since it was observed for the first time in Egypt especially in Beni-Sweif governorate in 2013, causing complete crop losses in some fields (Hilal and Ghebrial, 2014 & Ghebrial and Nada, 2017). Basil downy mildew has been previously reported as destructive disease in several countries (McLeod *et al.*, 2006; Wick and Brazee, 2009; Nagy and Horvath, 2011; Saude *et al.*, 2013 and Kong *et al.*, 2015).

Epidemiology of basil downy mildew strongly depends upon weather conditions. The major environmental factors are air humidity, temperature, light and wind speed. Relative humidity seems to be the predisposing factor for the attacks of *Peronospora belbahrii* on basil (Garibaldi *et al.*, 2007). Downy mildew on basil found to be particularly severe when foliage was kept wet (relative humidity ≥ 95 %) for at least 6 to 12 h immediately after inoculation at 18 ^{0}C, whereas at 12 and 27 ^{0}C, the disease was suppressed (Garibaldi *et al.*, 2007 and Cohen *et al.*, 2013). The use of fungicides is considered one of the most effective ways to protect many crops from downy mildew infection (Gullino *et al.*, 2009) but this is unsuitable for basil as medicinal crop, due to the risk of the presence of residues at harvest. However, there are reports on the development of resistant isolates to the fungicide mefenoxam within a year from application (Cohen *et al.*, 2013). The use of basil resistant varieties is a promising and safe method for disease control but the unavailability of commercially resistant basil varieties in Egypt and a long term cross breeding programme is required to obtain new resistant cultivars, intensifies the need for alternative methods for disease control. As compared to these strategies, the disease can better be managed by cultural practices such as time of sowing, row and plant spacing, irrigation and other nutritional requirements (Wyenandt *et al.*, 2015 & Ghebrial and Nada, 2017). Sowing dates play an important role to control plant diseases in general and downy mildew in particular (Jeger *et al.*, 1998; Duvnjak *et al.*, 2005; Zarafi, 2005 and González *et al.*, 2011). It can be an effective means of control in many instances where other control measures are not available or impracticable (Pratap *et al.,* 1993). Change in climate may alter growth stages, rates of development in the life cycle and consequently, epidemic of pathogens as well as modify the physiology and resistance of host plants (Chakraborty and Datta, 2003). Singh *et al.* (1993) and Chahal *et al.* (1994) reported that crops sown early in the season before sporangial inoculum level have built up, usually escape infection or have very low infection by soil-borne oospores. Thakur (1992) recorded that delayed planting dates results in an increased incidence of downy mildew. Also cultivation date plays an important role in the performance, production and consequently the yield of medicinal and aromatic plants. Changing in planting date leads to significant changes in the weather which affects the total period of plant growth and exposure to the environment. Planting date may influence the crop productivity and its inner components (Ebrahimi *et al.*, 2010; Ejimofor Ogbonna and Gbacinku Umar-Shaba, 2012 and Ehsanullah *et al.*, 2014). This experiment was, therefore, undertaken to find out the optimum sowing date to manage downy mildew and to achieve maximum yields in basil.

Materials and Methods

A two-year field experiment was conducted under natural infection in the Experimental Farm of Sids Agricultural Research Station, Agric. Res. Center, Beni-Sweif governorate during the seasons of 2016 and 2017 to find out the optimum sowing date to manage downy mildew and to achieve maximum yields in basil. The soil of the experimental field is clay in texture (16.5 % sand, 30.1 % silt, 53.4 % clay), pH of 8.1, EC 1.2 dSm^{-1}; 1.3 % organic matter and 26.2, 10.1 and 176 ppm available N, P and K, respectively. The experiment was designed in a randomized complete blocks design arrangement, with three replications. The experimental plot size was 3 x 3.5 m.

In each season, the soil was mechanically ploughed and planked twice. During the preparation for cultivation, a mixture of calcium super-phosphate (15.5 % P_2O_5) as a source of phosphorus and potassium sulfate (48 % K_2O) as a source of potassium was added at the rate of 200 and 100 kg/fed, respectively. Basil seeds (Balady variety) were sown at the rate of 6-7 kg/fed. on five different sowing dates *i.e.,* 15th februery; 1st March; 15th March; 1st April and 15th April in the two experimental seasons. Weeds were removed by manual operations as needed and plants were irrigated regularly as necessary, throughout the growing season in order to maintain constant growth. Nitrogen was applied in the form of ammonium sulphate (20.6 % N), at the rate of 400 kg/fed. (recommended rate) as follow: the first one (100 kg/fed.) was added after 21 days from sowing seeds and the second amount (100 kg/fed.) was after 15 days from the first application. The remainder amounts were added after each cut. Monitoring and scouting the plants were carried out weekly for downy mildew, disease incidence and severity were estimated as follow:

Disease incidence:

Percentage of disease incidence was recorded as the number of diseased plants relative to the number of growing plants for each sowing date, and then the average of disease incidence was calculated.

Disease severity:

Percentage of disease severity was recorded according to the following equation (Abd-Alla, 2004):

$$\text{Disease severity } \% = [\sum (n \times c)] / (N \times C) \times 100$$

Whereas: n = Number of infected leaves, c = Category number, N = Total number of examined leaves and C = The highest category number of infection.

The plants were harvested three times during each growing season when the basil plants had full flowers by cutting the vegetative parts of the plants 10 cm above the soil surface with three replications in each cut. Fresh and dry weights of herb yield (ton/fed.) were determined. Data were statistically analyzed for computing L.S.D. test at 5 % probability according to the procedure outlined by Snedecor and Cochran (1989).

Results

Results in Tables 1 and 2 reveal significant differences in mean percent disease incidence of downy mildew in sweet basil plants with different sowing dates. Generally, the incidence of downy mildew was significantly higher in the April planting compared with the March and February plantings in both years. Disease was first observed in the plots on 15th April (35 days after sowing) which recorded high mean percent in disease incidence 54.1 % in the first cut, and the highest, being 98.8 % in the second cut and 100.0 % in the third cut during the growing season 2016. The same trend was recorded, 54.9, 99.1 and 100.0 % for the three plant cuts, respectively in the second growing season (2017), followed by the sowing date of 1st April. Sowing basil plants in March 1st and March 15th showed moderate disease incidence with no significant difference between them except in the first plant cut. The corresponding mean values in downy mildew incidence with the sowing date of

March 1st were 4.5, 82.9 & 99.2 % and with the sowing date of March 15th, being 9.9, 83.4 and 99.3 %, respectively for the three plant cuts through 2016 growing seasons. The same trend was observed with the second growing season (2017). On the other hand initial symptoms of downy mildew in February plantings began to appear on some plants approximately 69 and 70 days, respectively after seeding and recorded the minimum disease incidence 1.3 % in the first cut, 78.7 % in the second cut and 98.4 % in the third cut during the growing season 2016 and recorded 0.8, 75.5 and 98.2 % for the three plant cuts, respectively in the second growing season (2017).

Table 1. Evaluation the effect of sowing dates on the incidence of basil downy mildew through the three plant cuts during 2016 growing season under field conditions

Sowing dates	Incubation period/day	Disease incidence %					
		2016 growing season					
		1st cut					
		30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Mean
15th February	69	0.0	0.0	0.0	0.0	6.6	1.3
1st March	58	0.0	0.0	0.0	7.0	15.4	4.5
15th March	49	0.0	0.0	7.7	17.7	23.9	9.9
1st April	40	0.0	14.0	39.4	60.7	76.5	38.1
15th April	35	0.0	41.0	58.1	77.3	94.0	54.1
L.S.D. at 0.05		ns	2.1	3.0	3.2	3.9	---
2nd cut							
Sowing dates		**7 DAC**	**14 DAC**	**21 DAC**	**28 DAC**	**35 DAC**	**Mean**
15th February		45.3	60.0	88.3	100.0	100.0	78.7
1st March		53.0	65.0	96.5	100.0	100.0	82.9
15th March		53.7	66.3	97.0	100.0	100.0	83.4
1st April		68.6	84.0	100.0	100.0	100.0	90.5
15th April		93.8	100.0	100.0	100.0	100.0	98.8
L.S.D. at 0.05		4.0	3.3	2.0	ns	ns	---
3rd cut							
Sowing dates		**7 DAC**	**14 DAC**	**21 DAC**	**28 DAC**	**35 DAC**	**Mean**
15th February		91.9	100.0	100.0	100.0	100.0	98.4
1st March		95.8	100.0	100.0	100.0	100.0	99.2
15th March		96.3	100.0	100.0	100.0	100.0	99.3
1st April		100.0	100.0	100.0	100.0	100.0	100.0
15th April		100.0	100.0	100.0	100.0	100.0	100.0
L.S.D. at 0.05		3.0	ns	ns	ns	ns	---

DAS: Day after sowing and DAC: Day after cutting.

Table 2. Evaluation the effect of sowing dates on the incidence of basil downy mildew through the three plant cuts during 2017 growing season under field conditions

Sowing dates	Incubation period/day	Disease incidence %					
		2017 growing season					
		1st cut					
		30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Mean
15th February	70	0.0	0.0	0.0	0.0	4.2	0.8
1st March	60	0.0	0.0	0.0	6.6	13.7	4.1
15th March	48	0.0	0.0	7.3	14.0	20.1	8.3
1st April	41	0.0	15.0	37.6	55.8	70.0	35.7
15th April	35	0.0	39.6	58.9	79.3	96.5	54.9
L.S.D. at 0.05		ns	4.1	3.4	4.2	4.0	---
		2nd cut					
Sowing dates		**7 DAC**	**14 DAC**	**21 DAC**	**28 DAC**	**35 DAC**	**Mean**
15th February		41.4	57.8	85.6	92.7	100.0	75.5
1st March		52.8	63.7	94.3	100.0	100.0	82.2
15th March		53.1	63.0	96.8	100.0	100.0	82.6
1st April		66.9	89.2	100.0	100.0	100.0	91.2
15th April		95.5	100.0	100.0	100.0	100.0	99.1
L.S.D. at 0.05		4.9	2.8	4.5	2.4	ns	---
		3rd cut					
Sowing dates		**7 DAC**	**14 DAC**	**21 DAC**	**28 DAC**	**35 DAC**	**Mean**
15th February		91.0	100.0	100.0	100.0	100.0	98.2
1st March		94.2	100.0	100.0	100.0	100.0	98.8
15th March		95.0	100.0	100.0	100.0	100.0	99.0
1st April		98.0	100.0	100.0	100.0	100.0	99.6
15th April		99.8	100.0	100.0	100.0	100.0	100.0
L.S.D. at 0.05		2.8	ns	ns	ns	ns	---

DAS: Day after sowing and DAC: Day after cutting.

Downy mildew severity in sweet basil is influenced by sowing dates (Tables, 3 and 4). There were significant differences among the treatments in respect to downy mildew severity. Severity of downy mildew was higher in 2016 than in 2017 growing seasons when comparing mean percent of disease severity pooled overall sowing dates. It is possible that the environment was more conducive to disease development in 2016 than in 2017, resulting in higher overall ratings. In general, early sown crops (February and March) originated lower disease severity than late sown crops (April). The disease development of downy mildew was initially slow and later increased. In the first growing season (2016), minimum disease severity was observed with the sowing date of February 15th which recorded 0.4, 59.5 and 58.8 %, respectively for the three plant cuts.

Sowing basil seeds on March 1st showed moderate disease severity followed by sowing date of March 15th with no significant differences between them except in the first plant cut during the two growing seasons. In March 1st sowing date, the first appearance of sweet basil downy mildew was observed at 58 days after sowing (DAS) subsequently, it developed in linear way. Disease severity percent was the lowest at 60 DAS (3.0 %) and increased throughout the cropping period and plant cuts and was at the peak during the second plant cut, i.e. 35 day after cutting (DAC), being **85.2** % and then decreased in the third plant cut (60.6-70.2 %). This may be due to the beginning of the unfavourable environment to disease development. Where, in March 15th sowing date, the first appearance of disease was observed at 49 DAS. Disease severity percent was 3.2 at 50 DAS, 10.9 at 60 DAS & 17.0 % at 70 DAS in the 1st cut, increased in the 2nd cut (48.9-**85.9** %) and then decreased in the 3rd cut which recorded 62.0-70.8 %. As the sowing date of basil plants was delayed with different intervals from 1st April to 15th April, this resulted in increasing severity of downy mildew which recorded the highest values when basil seeds were sown in April 15th (33.0, 85.8 and 83.6 % through the three plant cut, respectively) during 2016 growing season. The same trend was obtained in 2017 growing season.

The differences in herb fresh and dry weights were significant among the different dates of sowing (Tables, 5 and 6). Maximum fresh & dry weights were obtained when sweet basil seeds were sown on March 15th which was at par in the two growing seasons and recorded (26.1 and 5.7 ton/fed.) and (27.5 and 6.2 ton/fed.), respectively followed by the sowing date of March 1st treatment (24.6 and 4.5 ton/fed.) and (25.6 and 4.9 ton/fed.), respectively. The sowing date of April 1st treatment gave moderate values of fresh and dry weights. The corresponding mean values in 2016 growing season were 6.2, 7.7 & 6.5 and 1.3, 1.6 & 1.4 ton/fed. and **7.0**, 7.6 & 7.2 and 1.3, 1.8 & 1.5 ton/fed for the three plant cuts, respectively in the second growing season, 2017. Whereas, minimum fresh and dry yields were recorded with the sowing date of February 15th, the mean values for the three plant cuts were 3.2, 5.9 & 4.0 and 0.6, 1.2 & 1.0 ton/fed., respectively during the first growing season, 2016. This may be due to the unfavourable environmental conditions on growth and development of basil plant followed by the sowing date of April 15th treatment. This can be attributed to the higher percent of disease severity in the treatment of April 15th sowing date, which lead to higher defoliation of leaves.

Table 3. Evaluation the effect of sowing dates on basil downy mildew severity percent through the three plant cuts during 2016 growing season under field conditions

Sowing dates	Incubation period/day	Disease severity %					
		2016 growing season					
		1st cut					
		30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Mean
15th February	69	0.0	0.0	0.0	0.0	2.0	0.4
1st March	58	0.0	0.0	0.0	3.0	11.6	2.9
15th March	49	0.0	0.0	3.2	10.9	17.0	6.2
1st April	40	0.0	12.4	29.1	40.0	45.5	25.4
15th April	35	0.0	25.2	39.6	47.0	53.2	33.0
L.S.D. at 0.05		ns	2.6	3.1	1.7	3.7	---
2nd cut							
Sowing dates		7 DAC	14 DAC	21 DAC	28 DAC	35 DAC	Mean
15th February		33.7	43.1	66.6	72.1	81.8	59.5
1st March		48.3	55.0	71.2	76.5	85.2	67.2
15th March		48.9	56.2	74.6	78.0	85.9	68.7
1st April		58.3	72.6	80.5	87.3	92.7	78.3
15th April		73.4	80.6	86.0	91.4	97.4	85.8
L.S.D. at 0.05		5.4	6.1	4.5	3.1	3.1	---
3rd cut							
Sowing dates		7 DAC	14 DAC	21 DAC	28 DAC	35 DAC	Mean
15th February		50.0	56.2	60.3	62.4	65.0	58.8
1st March		60.6	64.9	67.2	68.0	70.2	66.2
15th March		62.0	65.1	68.7	69.2	70.8	67.2
1st April		68.9	74.5	78.9	82.5	84.6	77.9
15th April		76.4	80.5	84.1	87.2	89.7	83.6
L.S.D. at 0.05		3.4	3.2	3.2	4.1	4.1	---

DAS: Day after sowing and DAC: Day after cutting.

Table 4. Evaluation the effect of sowing dates on basil downy mildew severity percent through the three plant cuts during 2017 growing season under field conditions

Sowing dates	Incubation period/day	Disease severity %					
		2017 growing season					
		1st cut					
		30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Mean
15th February	70	0.0	0.0	0.0	0.0	1.2	0.2
1st March	60	0.0	0.0	0.0	2.1	8.7	2.2
15th March	48	0.0	0.0	2.9	10.3	16.5	5.9
1st April	41	0.0	11.6	26.2	38.2	45.0	24.2
15th April	35	0.0	21.0	35.6	44.4	49.7	30.1
L.S.D. at 0.05		ns	4.1	3.4	4.2	4.0	---
2nd cut							
Sowing dates		7 DAC	14 DAC	21 DAC	28 DAC	35 DAC	Mean
15th February		41.0	46.0	66.8	73.4	83.2	62.1
1st March		42.8	54.1	66.0	73.1	82.0	63.6
15th March		43.0	55.7	67.0	77.2	83.6	65.3
1st April		54.6	72.2	75.3	84.3	95.1	76.3
15th April		67.0	79.9	80.5	89.6	95.2	82.4
L.S.D. at 0.05		4.9	2.8	4.5	2.4	ns	---
3rd cut							
Sowing dates		7 DAC	14DAC	21 DAC	28 DAC	35 DAC	Mean
15th February		52.4	56.7	61.2	62.8	66.2	59.9
1st March		54.6	59.7	64.2	66.9	67.0	62.5
15th March		55.3	60.0	63.4	68.0	68.2	63.0
1st April		64.8	67.2	75.3	78.4	81.7	73.5
15th April		71.7	75.2	79.5	87.1	92.9	81.3
L.S.D. at 0.05		2.7	ns	ns	ns	ns	---

DAS: Day after sowing and DAC: Day after cutting.

Table 5. Effect of sowing dates on herb fresh weight (ton/fed) of the three plant cuts during the two growing seasons 2016 and 2017 under field conditions

Sowing dates	Season of 2016				Season of 2017			
	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	Total
15th February	3.2	5.9	4.0	13.1	3.9	5.5	4.1	13.5
1st March	6.1	10.5	8.0	24.6	7.0	10.3	8.3	25.6
15th March	7.0	10.3	8.8	26.1	7.7	10.9	8.9	27.5
1st April	6.2	7.7	6.5	20.4	7.0	7.6	7.2	21.8
15th April	5.5	6.0	4.2	15.7	5.6	5.9	4.4	15.9
L.S.D. at 0.05	0.7	0.8	0.8	---	0.8	0.9	0.9	---

Table 6. Effect of sowing dates on herb dry weight (ton/fed) of the three plant cuts during the two growing seasons 2016 and 2017 under field conditions

Sowing dates	Season of 2016				Season of 2017			
	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	Total
15th February	0.6	1.2	1.0	2.8	0.8	1.1	1.0	2.9
1st March	1.2	1.8	1.5	4.5	1.4	1.9	1.6	4.9
15th March	1.5	2.3	1.9	5.7	1.8	2.5	1.9	6.2
1st April	1.3	1.6	1.4	4.3	1.3	1.8	1.5	4.6
15th April	1.1	1.3	1.2	3.6	1.1	1.4	1.1	3.6
L.S.D. at 0.05	0.2	0.3	0.3	---	0.1	0.3	0.2	---

Discussion

Planting date has been reported as an important factor in epidemics of basil downy mildew. One prominent difference among planting dates was environmental conditions (temperature, relative humidity, light and wind speed) which strongly decide the epidemic of downy mildew. These environmental factors are being used to forecast the disease severity. Further, the knowledge of weather conditions for the development and spread of the disease is important to organize agro advisory services to the farmers to take up timely management practices. The present study demonstrated that percentages of incidence and severity of basil downy mildew were significantly higher with the delayed basil sowing (April sowing date). This is primarily can be attributed to the environmental conditions which were more favourable for infection process and fungus sporulation. Cohen and Ben-Naim (2016) considered that periods of ≥ 4 h with relative humidity ≥ 95 % are conducive for infection of basil with downy mildew and periods of ≥ 7 h with relative humidity ≥ 95 % are conducive for sporulation of *P. belbahrii* at 18°C. The early sown crops are able to escape infection or have only a low disease incidence and severity. This may be due to conditions which are unfavorable for the production of sporangia or sporangial inocula levels have not built up. Conversely, a crop planted when sporangia are abundant will be severely affected. Thakur (1992) recorded an increased incidence of pearl millet downy mildew when sowing was delayed. Similar results were reported by Singh *et al.* (1993) and Chahal *et al.* (1994). The best sowing time for basil in Egypt, therefore, is between mid March, when the crop is likely to get low infection and high yield.

In view of the sensitivity of basil to climatic factors especially to photoperiod and temperature, it is essential that sowing should be done on time so that there have enough time for vegetative growth. Basil is a warm season crop that requires high temperatures for growth and development. This can explain the reduction in fresh and dry weights of basil plants sown early in the February 15^{th}. Yield loss due to unfavorable sowing date has been reported by Sadeghi (2009); Kumar *et al.* (2017). With delayed sowing, plant development is accelerated because the crops encounter higher temperatures during the vegetative growth. In this study, as the sowing date of basil plants was delayed with different intervals from 1^{st} April to 15^{th} April resulted in decreasing fresh and dry yields due to increasing severity of downy mildew that lead to higher defoliation among plants.

According to the results of this research we concluded that basil is sensitive to climatic factors especially to photoperiod and temperature, adjusting the planting date to avoid high downy mildew severity is an impractical control method. The development and cultivation of sweet basil in between mid March provided protection against downy mildew infection and affected disease severity at an important level as well as increased yields of sweet basil. Consequently, the incorporation of this sowing date in an integrated management programs should bring positive results, both in terms of reducing disease intensity and the amount of fungicides used.

R e f e r e n c e s

Abd-Alla, F.M.F. 2004. Studies on Powdery Mildew Disease Affecting Solanaceous Plants. M.Sc. Thesis, Fac. Agric., Cairo Univ., Cairo.

Belbahri, L.; Calmin, G.; Pawlowski, J. and Lefort, F. 2005. Phylogenetic analysis and real time PCR detection of a presumably undescribed *Peronospora* species on sweet basil and sage. *Mycol. Res.*, **109**:1276-1287.

Chahal, S.S.; Thakur, R.P. and Mathur, S.B. 1994. Seed borne diseases and seed health testing of pearl millet. *Danish Govt. Institute of Seed Pathology for Developing Countries, Copenhagen, Denmark,* 27 pp.

Chakraborty, S. and Datta, S. 2003. How will plant pathogens adapt to host plant resistance at elevated CO_2 under a changing climate? *New Phytologist*, **159**: 733-742.

Cohen, Y. and Ben-Naim, Y. 2016. Nocturnal fanning suppresses downy mildew epidemics in sweet basil. *PLoS One* **11**(5):e0155330.

Cohen, Y.; Vaknin, M.; Ben-Naim, Y. and Rubin, A.E. 2013. Light suppresses sporulation and epidemics of *Peronospora belbahrii*. *PLoS One* **8**(11): e81282.

Duvnjak, T.; Vratarić, M.; Aleksandra Sudarić, A.; Jasenka Čosić, J.; Vrandečić, K.; Krizmanić, M. and Mijić, A. 2005. Occurrence and intensity of downy mildew on soybean seed in relation to planting date. *Sjemenarstvo*, **22**(3-4): 101-110.

Ebrahimi, A.; Moaveni, P. and Farahani, H.A. 2010. Effects of planting dates and compost on mucilage variations in borage (*Borago officinalis* L.) under different chemical fertilization systems. *Inter. J. Biotech .Mole.Biolo. Res.*, **1**(5): 58-61.

Ehsanullah, S.A.A.; Ashraf, U.; Rafiq, H.; Tanveer, M. and Khan, I. 2014: Effect of sowing dates and weed control methods on weed infestation, growth and yield of direct-seeded rice. *The Philippine Agricultural Scientist*, **97**: 307-312.

Ejimofor Ogbonna, P. and Gbacinku Umar-Shaba, Y. 2012: Time of sowing affects the growth and yield of sesame in a derived savanna agroecology of south-eastern Nigeria. *The Philippine Agricultural Scientist*, **95**: 153-159.

Elgayyar, M.; Draughon, F.A.; Golden, D.A. and Mount, J.R. 2001. Antimicrobial activity of essential oils from plants against selected pathogenic and saprophytic microorganisms. *J. Food Prot.*, **64**: 1019-1024.

Garibaldi, A.; Bertetti, D. and Gullino. M.L., 2007. Effect of leaf wetness duration and temperature on infection of downy mildew (*Peronospora* sp.) of basil. *J. Plant Dis. Prot.*, **114**:6-8.

Garibaldi, A.; Minuto, G.; Bertelli, D. and Gullino, M.L., 2004. Seed transmission of *Peronospora* sp. of basil. *J. Plant Dis. Plant Prot.*, **111**(5): 465-469.

Ghebrial, Eman W.R. and Nada, M.G.A., 2017. Suppression of basil downy mildew caused by *Peronospora belbahrii* using resistance inducers, mineral salts and antitranspirants combined with different rates of nitrogen fertilizer under field conditions. *Egypt. J. Phytopathol.*, **45**(1): 71-97.

González, P.H.; Colnago, P.; Peluffo, S.; Idiarte, H.G.; Zipitría, J. and Galván, G.A. 2011. Quantitative studies on downy mildew (*Peronospora destructor* Berk. Casp.) affecting onion seed production in southern Uruguay. *Eur. J. Plant Pathol.*, **129**: 303-314.

Gullino, M.L.; Gilardi, G. and Garibaldi, A. 2009. Chemical control of downy mildew on lettuce and basil under greenhouse. *Communications in Agricultural and Applied Biological Sciences*. **74**(3): 933-940.

Hilal, A.A. and Ghebrial, Eman W. 2014. Occurrence of downy mildew (*Peronospora belbahrii*) of sweet basil (*Ocimum basilicum* L.) in Egypt. *Egypt. J. Phytopathol.*, **42**(2): 197-198.

Hussain, A.I.; Anwar, F.; Hussain Sherazi, S.T. and Przybylski, R. 2008. Chemical composition, antioxidant and antimicrobial activities of basil (*Ocimum basilicum*) essential oils depends on seasonal variations. *Food Chem.*, **108**: 986-995.

Jeger, M.J.; Gilijamse, E.; Bock, C.H. and Frinking, H.D. 1998. The epidemiology, variability and control of the downy mildews of pearl millet and sorghum with particular reference to Africa. *Plant Pathol.*, **47**: 544-569.

Koroch, A.R.; Wang, W.; Michael, T.P.; Dudai, N.; Simon, J.E. and Belanger, F.C. 2010. Estimation of nuclear DNA content of cultivated *Ocimum* species by using flow cytometry. *Isr. J. Plant Sci.*, **58**: 183-189.

Kong, X.Y.; Wang, S.; Wan, S.L.; Xiao, C.L.; Luo, F. and Liu, Y. 2015. First report of downy mildew on basil (*Ocimum basilicum*) in China. *Plant Dis.*, **99**(11): 1642.

Kumar, U.; Singh, A.K.; Jha, P.K. and Patel, P. 2017. Effect of planting time and spacing on plant growth, yield and oil yield of tulsi (*Ocimum sanctum*). *Bull. Env. Pharmacol. Life Sci.*, **6**(1): 305-309.

McLeod, A.; Coertze, S. and Mostert, L. 2006. First report of a *Peronospora* species on sweet basil in South Africa. *Plant Dis.*, **90**(8): 1115.

Nagy, G. and Horvath, A. 2011. Occurrence of downy mildew caused by *Peronospora belbahrii* on sweet basil in Hungary. *Plant Dis.*, **95**: 1034.

Pratap, M.; Swamy, G.S. and Babu, R.S.H. 1993. Studies on optimum date of sowing and spacing for okra. *J. Res.*, **21**: 222-226.

Sadeghi, S.; Rahnavard, A. and Ashrafi, Z.Y. 2009. The effect of plant-density and sowing date on yield of basil (*Ocimum basilicum* L.) in Iran. *J. Agric. Technol.*, **5**(2): 413-422.

Saude, C.; Westerveld, S.; Filotas, M. and McDonald, M.R. 2013. First report of downy mildew caused by *Peronospora belbahrii* on basil (*Ocimum* spp.) in Ontario. *Plant Dis.*, **97**(9): 1248.

Simon, J.E.; Quinn, J. and Murray, R.G. 1990. "Basil: A Source of Essential Oils"., In: Janick, J. and Simon, J.E. (eds.). "*Advances In New Crops*". Timber Press, Portland, OR. pp 484-489.

Singh, S.D.; King, S.B. and Werder, J. 1993. Downy mildew disease of pearl millet. *ICRISAT. Info. Bull.*, **37**: 30.

Snedecor, G.W. and Cochran, W.G. 1989. "*Statistical Methods*". 8th. ed. Iowa State Univ. Press, Ames, Iowa, USA, 251 pp.

Suppakul, P.; Miltz, J.; Sonneveld, K. and Bigger, S.W. 2003. Antimicrobial properties of basil and its possible application in food packaging. *J. Agric. Food Chem.*, **51**: 3197-3207.

Thakur, P.D. 1992. Pearl Millet Downy Mildew. In “Plant Diseases of International Importance” (Singh, U.S. Mukhopadhyay, A.N. Kumar, J. Chaude, H.S., eds.). Diseases of Pulses and Cereals 1. Englewood Cliffs. pp 298-301.

Thines, M.; Telle, S.; Ploch, S. and Runge, F. 2009. Identity of the downy mildew pathogens of basil, coleus and sage with implications for quarantine measures. *Mycol. Res.*, **113**:532-540.

Wyenandt, C.A.; Simon, J.E.; Pyne, R.M.; Homa, K.; McGrath, M.T.; Zhang, S.; Raid, R.N.; Ma, L.-J.; Wick, R.; Guo, L. and Madeiras, A. 2015. Basil downy mildew (*Peronospora belbahrii*): Discoveries and challenges relative to its control. *Phytopathology*, **105**: 885-894.

Wick, R.L. and Brazee, N.J. 2009. First report of downy mildew caused by a *Peronospora* species on sweet basil (*Ocimum basilicum*) in Massachusetts. *Plant Dis.*, **93**(3): 318.

Zarafi, A.B. 2005. Early sowing and metalaxyl seed treatment reduced incidence of pearl millet downy mildew [*Sclerospora graminicola* (Sacc.)] in Samaru, Nigeria. *J. Plant Prot. Res.*, **45**(3): 163-169.

Zheljazkov, V.D.; Cantrell, C.L.; Tekwani, B. and Khan, S.I. 2008. Content, composition and bioactivity of the essential oils of three basil genotypes as a function of harvesting. *J. Agric. Food Chem.*, **56**: 380-385.

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تـأثير مواعيد الـزراعة على تطور مـرض البيــاض الزغبى فى الريحان والذى يسببه فطر بيرونوسبورا بيلبارى تحت ظروف الحقل الطبيعية

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تم اجراء تجارب فى الحقل تحت ظروف العدوى الطبيعية بمرض البياض الزغبى فى الريحان خلال عامى 2016 و 2017 فى المزرعة البحثية بمحطة البحوث الزراعية بسدس-مركز البحوث الزراعية-محافظة بنى سويف لدراسة تأثير مواعيد الزراعه على وبائية مرض البياض الزغبي والذى يسببه فطر بيرونوسبورا بيلبارى وانتاجية نباتات الريحان الحلو. تم زراعة بذور الريحان الحلو فى مواعيد زراعة مختلفة: ميعاد مبكر (شهر فبراير)، ميعاد وسط (شهر مارس) و ميعاد متأخر (شهر أبريل). عموما سببت الزراعة المبكرة انخفاضا معنويا فى نسبة وشدة الأصابة مقارنة بالزراعة المتأخرة. على الرغم من أن مواعيد الزراعة المبكرة (شهر فبراير) أحدثت أعلى انخفاض فى نسبة وشدة الأصابة بالمرض ولكنها أثرت بشكل كبير على نمو النبات والمحصول الى أدنى قيمة. تم الحصول على أعلى فعالية فى انخفاض نسبة وشدة الأصابة بالمرض عند زراعة بذور الريحان الحلو فى 15 مارس مما أدي الى زيادة المحصول الطازج والجاف للعشب.