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Response of Onion (*Allium cepa* L.) to sowing dates

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Onion are the third most important vegetable crop sold in South Africa. Optimum sowing dates for new cultivars was determined in Bloemfontein (South Africa) during 2009 and 2010. Cultivars planted in 2009 and 2010 were 'Charlize', 'Jaquar', 'Python', (South Wester, 2009; Ceres Gold, 2010). Unavailability of 'South Wester' seed resulted in replacement with 'Ceres Gold'. In 2009 onion seeds were sown on 30 April, 7 and 21 May and in 2010 on 11, 25 May and 8 June. Trials were laid out as a randomized complete block design with each treatment combination replicated 3 times. Plant height and leaf number were measured 18 weeks after emergence. At harvest, bulb yield and quality were recorded. Cultivars differed with respect to growth habit, bulb size, neck diameter and bolting, but not bulb fresh mass and yield. Sowing date did not influence plant height and leaf number significantly, except in 2010 where the early sowing dates resulted in taller plants. The respective delayed sowing dates in 2010 (11 May, 25 May, 8 June) significantly decreased average bulb fresh mass (71.48, 49.42, 49.21 g bulb^{-1}) and yield (40.96, 34.05, 28.20 t ha^{-1}). In both seasons thinner necks were recorded for later planting dates. Cultivars tested in Bloemfontein can be sown from late April to late May, although the best results were obtained from sowing in May.

Key words: Bolting, bulb diameter, bulb neck diameter, bulb shape, bulb yield, leaf number, photoperiod, plant height, temperature.

INTRODUCTION

Onions are considered to be the third most important South African vegetable crop after potatoes and tomatoes, earning an income of approximately R 12.5 billion per annum (approximately € 1.06 billion per annum) (The Agricultural Directory, 2011). Onion development is dependent on environmental conditions such as photoperiod and temperature as well as growth rate and the number of days to maturity (Steer, 1980). During early growth and development, onions require cool temperatures (6 to 20°C), but during bulb initiation and development, warmer temperatures (25 to 27°C) are required (Comrie, 1997a; Ansari, 2007).

Lancaster et al. (1996) indicates that a minimum day length is necessary for each onion cultivar and that a plant needs to accumulate thermal time of approximately 600 degree days from emergence (growing degree days above 5°C). Both these requirements need to be met before bulb initiation will occur. Onion cultivars, classified as short day cultivars, require a day length duration of 11 to 12 h to initiate bulbs. Onions classified as intermediate day cultivars start to initiate bulbs when day length is between 12 to 14 h. Long day cultivars require a day length of more than 14 h for bulb initiation and cannot be planted in South Africa, because the longest average maximum day length is only 14.33 h (Smith, 2006). Due to the fact that photoperiod and temperature influences

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onion growth, and cultivars are also specific with regard to minimum day length required for bulbing, time of sowing is critical and may also differ from year to year (Brewster, 2008).

Although there is no minimum plant size for bulbing, larger plants tend to initiate bulbs earlier even though the required photoperiod is not met (Smittle, 1993). Sowing dates should therefore be chosen to ensure that growth takes place under optimum temperatures (6 to 20°C) (Brewster, 2008). Larger plants are more prone to the production of split or double bulbs, which contribute to poor quality (Comrie, 1997a). High temperatures (25 to 27°C) accelerate bulb initiation causing it to occur at a slightly shorter day length than required for a specific cultivar (Van den Berg et al., 1997). However, if bulbing is stimulated when plants are still small, leave senescence will occur rapidly and small bulbs will be produced due to a small leaf area (Wickramasinghe et al., 2000; Brewster, 2008). Low temperatures (9 to13°C) close to bulb formation will cause plants to bolt instead of forming bulbs even though day length is long enough for bulbing. Early sown plants will reach bulb formation stage when temperatures are still low and these plants will bolt instead of forming bulbs (Comrie, 1997a). This will result in lower yields of a poor quality (Khokhar et al., 2007).

Time of sowing is therefore important so that every developmental phase may occur at times when temperature and photoperiod is favourable for crop performance and high yields can be obtained. Therefore, the objective of the current study was to determine the optimum sowing date for different onion cultivars under the existing climatic conditions of Bloemfontein, in the Central Free State Province of South Africa.

MATERIALS AND METHODS

Field trials were conducted at the University of the Free State in Bloemfontein during 2009 and 2010. Bloemfontein ((29°06'S and 26°18'E, 1395 m above sea level) is located in the Central Free State Province on the southern edge of the Highveld. The area is located within the semi-arid climate of the revised Köppen Climate Classification (Kruger, 2004) with hot summer days (annual average maximum temperature 24.4°C) and cold dry winters (annual average minimum temperature of 7.5°C) often with severe frost. It is a summer rainfall area with an annual average rainfall of 559 mm. Table 1 shows a summary of weather conditions during the 2 production seasons.

In the first experiment conducted during 2009, 4 onion cultivars and 3 sowing dates were evaluated (Table 2). This was repeated in 2010 (Table 2) using the same number of cultivars and sowing dates. However, seed of ‘South Wester’ was no longer available and was replaced with ‘Ceres Gold’, which is also a mid-intermediate day cultivar (Hygrotech, 2009). Sowing dates were delayed in 2010 due to heavy rainfall and the availability of seed. The increased plant density in 2010 was a result of the large bulbs obtained in 2009. Both experiments were laid out in a randomized complete block design, with each treatment combination replicated 3 times.

Soil samples were collected in both seasons from a depth of 15 cm prior to land preparation, dried and sent for analysis. Analyses were carried out according to standard methods of the non-affiliated soil analysis work committee (1990). Some chemical and physical properties of the soil of the 2 trial areas used in 2009 and 2010 are indicated in Table 3.

Results of the analyses were used to determine nutrient requirements according to the nutrient withdrawal amounts for onions (FSSA, 2007) at a targeted yield of 70 $t \cdot ha^{-1}$. These withdrawal amounts were 5, 0.5 and 2.4 kg ha^{-1}, for N, P and K, respectively (FSSA, 2007). In 2009, phosphorus (94 $kg \cdot ha^{-1}$) and nitrogen (282 $kg \cdot ha^{-1}$) were broadcast and incorporated into the soil before sowing using 3-1-0(30). All the potassium (280 $kg \cdot ha^{-1}$) was applied before sowing as KCl. A split application of the residual nitrogen was done using urea at 6 (34 $kg \cdot ha^{-1}$) and 12 weeks (34 $kg \cdot ha^{-1}$) after sowing. During 2010, phosphorus (46 $kg \cdot ha^{-1}$) and nitrogen (138 $kg \cdot ha^{-1}$) were broadcast and incorporated into the soil before sowing using 3-1-0(28). Differences in phosphorus application for 2009 and 2010 were to ensure that the minimum requirement (30 to 60 mg kg^{-1} Bray 1) in the soil was met. All the potassium (280 $kg \cdot ha^{-1}$) was applied before sowing using KCl. A split application of the residual nitrogen was done using urea at 6 (106 $kg \cdot ha^{-1}$) and 12 weeks (106 $kg \cdot ha^{-1}$) after sowing.

The soil was watered to field capacity before sowing. Seeds were sown by hand and covered with soil to a depth of 2 cm. A light irrigation was applied after sowing, using surface drip system with emitters spaced 30 cm in the line and with a delivery capacity of 2.1 L $H_2O \cdot h^{-1}$. Irrigation (1.78 mm) was done on a daily basis, except on days that it rained, to prevent soil from forming a crust that would delay emergence (Mondal et al., 1986). After emergence, irrigation (3.25 mm) was done every second day with a drip irrigation system to ensure sufficient water supply during the vegetative phase and daily (2.33 mm) from the start of bulb development until maturity.

Thinning plants to the required plant population (Table 2) took place 3 weeks after emergence. Weeds were controlled manually every week throughout the season. Sodium fluosilicate (Cutworm Bait - Efekto, Private Bag 215, Bryanston, 2021) was broadcast at a rate of 10 $g \cdot m^{-2}$ over the planting area after damage was noted during 2009. In 2010, the bait was applied as soon as the first seedlings emerged. Mercapthothin (Malasol - Efekto, Private Bag 215, Bryanston, 2021) was applied at a rate of 17.5 $ml \cdot 10\ L^{-1} H_2O$ using a knapsack sprayer whenever aphids or thrips were noticed on the onion plants.

Growth parameters were measured on 11 randomly selected plants located in the centre of each plot. Plant height and leaf number were measured at 18 weeks after emergence (when 10% of the foliage collapsed at maturity). Plant height was measured from the ground level to the tip of the highest leaf using a standard ruler. The number of fully developed active green leaves was counted. Bulb yield ($t \cdot ha^{-1}$) and quality parameters (bulb mass, size, and bulb neck diameter) were assessed on bulbs from the net plot size (Table 2) of the middle rows in each plot. Onions were lifted by hand when 100% of the foliage top per plot had collapsed. If necessary, the soil was first loosened using a garden fork. Onions were immediately transported to the laboratory and not left to cure.

After harvesting, leaves and roots were cut from the bulbs, and bulbs cleaned by washing with water and dried with tissue paper. After harvesting, bulbs were weighed separately to obtain fresh mass per bulb of 11 randomly selected bulbs harvested from the net plot. The fresh mass of all bulbs harvested from net plot size was expressed as $g \cdot m^{-2}$, and then converted to $t \cdot ha^{-1}$ in order to indicate onion yield. The same 11 bulbs randomly selected for fresh mass determination were also used to measure the quality parameter. The diameter of bulbs was measured at right angles to the longitudinal axis at the widest circumference of the bulb using a digital calliper. Thereafter, the bulbs were graded into extra small (10 to 34 mm), small (35 to 39 mm), medium (40 to 69 mm), large (70 to 89 mm) or extra-large (≥ 90 mm) bulbs (Joubert et al., 1997). The neck diameter was measured, 5 mm above the top of each bulb using a digital calliper. Bulb defects such as decay, bolting,

Table 1. Monthly average maximum and minimum temperatures, photoperiod and total rainfall from weather station for 2009 and 2010 (SAWS, 2010; South African Astronomical Observatory, 2009, 2010).

Month	Temperatures (°C)		Photoperiod (h)	Rainfall (mm)
	Maximum	Minimum		
2009				
January	30.28	16.60	13.45	120.90
February	26.67	16.15	13.31	97.80
March	27.17	13.60	12.05	21.30
April	24.97	10.55	11.24	11.90
May	20.00	5.84	10.39	20.60
June	16.38	4.18	10.18	27.40
July	15.71	-0.15	10.29	10.90
August	20.31	4.80	11.30	9.70
September	24.98	8.33	12.11	0.00
October	25.72	11.93	12.58	70.60
November	26.12	12.41	13.34	85.10
December	31.90	15.67	14.13	54.40
Average	24.18	9.99	12.03	44.23
Total rainfall				530.60
2010				
January	27.86	17.13	13.45	131.10
February	29.07	16.73	13.31	124.70
March	27.78	14.74	12.06	77.70
April	22.96	10.58	11.22	48.50
May	20.75	6.63	10.39	39.90
June	16.96	1.64	10.18	20.10
July	18.44	4.04	10.28	0.30
August	21.05	3.84	11.30	0.00
September	26.35	9.14	12.11	0.30
October	27.10	10.96	12.57	20.60
November	28.47	13.19	13.34	30.20
December	28.51	14.65	14.13	113.00
Average	24.61	10.27	12.03	50.53
Total rainfall				606.40

split and mechanical damage were observed to determine marketable bulbs. Bulb shape was determined by observation and classified according to the description of Van den Berg et al. (1997).

Analysis of variance was done on all measured parameters to determine the significance of differences between means of treatments using the NCSS 2000 statistical program (Hintze, 1999), and Tukey's test for the LSD ≤ 0.05, except where stated.

RESULTS AND DISCUSSION

Plant height and leaf number

Plant height of the different onion cultivars differed significantly from each other 18 weeks after emergence in both 2009 and 2010. Sowing date only significantly influenced plant height in 2010 (Table 4). 'Python' was significantly taller than 'Charlize' and 'South Wester' in 2009 and significantly taller than all the other cultivars planted in 2010. Onion plants sown on 25 May in 2010 were significantly taller than those plants sown earlier or later that same year.

Sowing onions on different dates did not significantly influence the number of leaves produced by plants in both 2009 and 2010 (Table 4). In 2010 cultivars differed in the number of leaves produced per plant (Table 4). 'Python' plants produced significantly more leaves (8.00) than 'Ceres Gold' (7.11) and 'Charlize' (7.44) plants, but not significantly more than 'Jaquar' (7.55).

The selected sowing dates did not have such a prominent effect on final plant height and number of leaves in this study. According to Brewster (2008) as soon as the required minimum day length of an onion cultivar is met and temperatures start to increase, bulbs will be initiated. Therefore, when the same cultivar is

Table 2. Different onion cultivars and sowing date treatments, plant population, spacing and plot size used in 2009 and 2010.

2009		2010	
Cultivar			
Name	**Type**	**Name**	**Type**
Charlize	Short day	Charlize	Short day
Jaquar	Early-intermediate	Jaquar	Early-intermediate
Python	Early-intermediate	Python	Early-intermediate
South Wester	Mid-intermediate	Ceres Gold	Mid-intermediate
Sowing date			
30 April		11 May	
7 May		25 May	
21 May		08 June	
Plant spacing (cm)			
In row	**Between row**	**In row**	**Between row**
8	30	5.5	30
Plant population			
m^{-2}	**ha^{-1}**	**m^{-2}**	**ha^{-1}**
41	416 667	61	606 061
Plot size (m^{-2})			
Gross	**Net**	**Gross**	**Net**
1.8	0.79	1.8	0.88

Table 3. Chemical and physical characteristics of the experimental sites.

Property	2009	2010
$pH_{(KCl)}$	5.5	4.7
Nutrients (mg kg^{-1})		
P (Bray 1)	20.2	28.1
K (NH_4OA_C)	154.7	233.8
Ca (NH_4OA_C)	1653	531
Mg (NH_4OA_C)	456.7	156.3
Na (NH_4OA_C)	18.1	10.7
CEC ($cmol_c kg^{-1}$)	12.48	4.73
Particle size distribution (%)		
Sand	54	67
Clay	15	12
Loam	31	21

sown at different times in the same area, plants will start forming bulbs at more or less the same time. Thus, those sown earlier will have a longer vegetative growth period and consequently have larger plants with more leaves (Comrie, 1997b). Plants sown earlier in this study did not have significantly more leaves or were not larger than plants sown later. The reason for this may be that the average day temperatures during the vegetative growth period for all the sowing dates did not differ much and ranged between 16.5 and 18.9°C. These temperatures are below the optimum for leaf growth of 20 to 25°C as indicated by Brewster (2008).

Cultivars in this study performed differently regarding their growth habit. 'Python' (early-intermediate day cultivar) tended to be a more aggressive grower and produced taller plants with more leaves although not always significant. Brewster (2008) reported that the growth of various onion cultivars differs, and will not be the same due to differences in genotype.

Bulb fresh mass and yield

Onion bulb fresh mass ($g \cdot bulb^{-1}$) and total yield ($t \cdot ha^{-1}$) of

Table 4. Influence of sowing date on plant height (cm) and leaf number of different onion cultivars 18 weeks after emergence.

Cultivar (C)	Plant height (cm)				Leaf number			
	2009							
	Sowing date (SD)			Avg(C)	Sowing date (SD)			Avg(C)
	30 Apr	7 May	21 May		30 Apr	7 May	21 May	
Charlize	58.58	51.06	55.07	54.90^{a*}	9.00	7.67	7.67	8.11
Jaquar	72.11	64.35	63.22	66.56^{ab}	9.33	8.33	8.67	8.78
Python	74.26	67.60	82.86	74.91^{b}	8.67	9.00	9.00	8.89
South Wester	54.67	57.31	68.93	60.30^{a}	8.33	7.67	8.67	8.22
Avg(SD)	64.91	60.08	67.52		8.83	8.17	8.50	
$LSD_{T(0.05)}$	C = 14.08	SD = ns	CxSD = ns		C = ns	SD = ns	CxSD = ns	
	2010							
Cultivar(C)	11 May	25 May	8 Jun	Avg(C)	11 May	25 May	8 Jun	Avg(C)
Charlize	47.64	51.91	43.00	47.52^{c*}	7.33	7.67	7.33	7.44^{a*}
Jaquar	54.97	57.33	44.58	52.29^{b}	7.33	8.00	7.33	7.55^{ab}
Python	56.21	60.15	53.64	56.67^{a}	8.00	8.00	8.00	8.00^{b}
Ceres Gold	42.48	48.39	39.00	43.29^{d}	7.00	7.33	7.00	7.11^{a}
Avg(SD)	50.33^{A**}	54.45^{B}	45.05^{C}		7.42	7.75	7.42	
$LSD_{T(0.05)}$	C = 2.72	SD = 2.13	CxSD = ns		C = 0.55	SD = ns	CxSD = ns	

C, Cultivar; **SD,** sowing date: **CxSD,** cultivar interaction with sowing date; **Avg,** average: **$LSD_{T(0.05)}$,** least significant difference; **ns,** not significant. *Means with different small cap letters (a, b, and c) in the same column differ significantly from each other. ** Means with different cap letters (A, B, and C) in the same row differ significantly from each other.

the cultivars were not significantly affected in 2009, but both were significantly affected in 2010 (Table 5). Even though there was no significant differences in bulb fresh mass of the different onion cultivars, 'Jaquar' bulbs were the heaviest in both seasons. Onion bulb fresh mass tended to be lower with delayed sowing dates, although the difference was not always significant. Significantly heavier onion bulbs were harvested in 2010 when plants were sown earlier (11 May) than later (25 May or 8 June). Onion bulb fresh mass of plants sown on the 2 later dates did not differ significantly from each other. As shown in Table 5, bulb yield followed the same trend for both parameters. The average fresh mass per onion bulb in 2009 (64.46 g) and 2010 (60.04 g) did not differ much, but the average yield between 2009 (25.68 t·ha^{-1}) and 2010 (34.40 t·ha^{-1}) differed by nearly 10 t·ha^{-1}. This may be because 2 different plant populations were used during the 2 seasons, with approximately 190 000 more plants ha^{-1} being planted in 2010 (Table 2). The best sowing date for all the cultivars when considering yield parameters was May. The highest yield was also recorded on 11 May 2010, which differed significantly from the other dates (Table 5).

Bulb diameter (size)

Bulb sizes of cultivars differed significantly from each other in 2009 (Table 5). 'Python' bulbs (72.20 mm) were significantly smaller than 'South Wester' (82.51 mm) and 'Jaguar' (80.50 mm) bulbs. 'Charlize' bulbs (79.78 mm) did not differ significantly in size from any of the other cultivars. Sowing date did not significantly affect bulb size (Table 5), but bulbs of plants sown the earliest (30 April) were the largest. Bulb diameter was significantly influenced by both cultivar and sowing date during 2010 (Table 5).'Ceres Gold' bulbs (60.06 mm) were significantly larger than those of 'Charlize' (53.66 mm) and 'Python' (54.28 mm) bulbs. No significant difference in bulb size between 'Jaquar' and 'Ceres Gold' occurred. Bulb diameter of onions sown on the 25 May (58.08 mm) was significantly greater than bulbs sown later on 8 June (53.79 mm).

Bulb size ranged between 72.20 and 82.51 mm in 2009 and from 53.66 to 60.06 mm in 2010. According to the local grading system used on the fresh produce markets, all the bulbs from 2009 graded as large (70 to 89 mm), while in 2010 the bulbs were graded as medium (40 to 69 mm). According to Kanton et al. (2002) consumers prefer medium bulbs above large bulbs and higher prices are consequently obtained on fresh produce markets for medium bulbs. Bulb size was also found to influence non-nutrient compounds in onions. Pérez-Gregorio et al. (2010) found that smaller onions had higher flavonol and anthocyanin content than larger bulbs.

Table 5. Influence of sowing date on bulb fresh mass, yield, bulb diameter and neck diameter of different onion cultivars.

Cultivar (C)	Bulb fresh mass (g·bulb^{-1})				Yield (t·ha^{-1})				Bulb diameter (mm)				Neck diameter (mm)			
	2009															
	Sowing date (SD)			Avg (C)	Sowing date (SD)			Avg(C)	Sowing date (SD)			Avg(C)	Sowing date (SD)			Avg(C)
	30 Apr	7 May	21 May		30 Apr	7 May	21 May		30 Apr	7 May	21 May		30 Apr	7 May	21 May	
Charlize	73.67	63.12	57.68	64.82	30.76	26.37	24.09	27.07	80.83	81.34	77.16	79.78^{ab*}	16.71	15.47	13.43	15.20^{a*}
Jaquar	78.35	70.77	71.41	73.51	32.73	29.56	29.83	30.71	84.77	74.35	82.38	80.50^{a}	20.51	17.45	15.05	17.67^{a}
Python	55.59	49.50	54.40	53.16	23.22	20.68	22.72	22.21	67.59	77.29	71.72	72.20^{b}	19.26	16.12	21.03	18.80^{b}
South Wester	76.84	74.43	47.77	66.35	32.10	31.09	19.95	22.71	82.43	81.05	84.05	82.51^{a}	23.48	21.41	22.76	22.55^{c}
Avg(SD)	71.11	64.46	57.82		29.70	26.93	24.15		78.91	78.51	78.83		19.99^{A**}	17.61^{B}	18.07^{A}	
LSD$_{T(0.05)}$	C = ns	SD = ns	CxSD = ns		C = ns	SD = ns	CxSD = ns		C = 8.14	SD = ns		CxSD = ns	C = 3.01	SD = 2.36		CxSD = ns
	2010															
Cultivar(C)	11 May	25 May	8 Jun	Avg(C)	11 May	25 May	8 Jun	Avg(C)	11 May	25 May	8 Jun	Avg(C)	11 May	25 May	8 Jun	Avg(C)
Charlize	70.02	67.46	45.86	61.11	40.13	38.65	26.28	35.02	52.59	57.01	51.37	53.66^{a*}	7.46	8.63	7.42	7.84^{a*}
Jaquar	70.59	65.90	54.27	63.59	40.45	37.76	31.10	36.44	56.21	63.95	52.76	57.64^{a}	9.10	9.95	8.23	9.09^{b}
Python	74.12	51.85	50.78	58.92	42.47	29.71	29.10	33.76	56.85	53.41	52.57	54.28^{a}	13.17	13.83	14.43	13.81^{c}
Ceres Gold	71.17	52.46	45.94	56.52	40.79	30.06	26.32	32.39	63.79	57.94	58.44	60.06^{b}	19.18	19.22	18.49	18.96^{d}
Avg(SD)	71.48^{A**}	59.42^{B}	49.21^{B}		40.96^{A**}	34.05^{B}	28.20^{B}		57.36^{A**}	58.08^{A}	53.79^{B}		12.23	12.91	12.14	
LSD$_{T(0.05)}$	C = ns	SD = 11.60	C x SD = ns		C = ns	SD = 6.64	CxSD = ns	C = 5.22	SD = 4.09	CxSD = ns			C = 1.12	SD = ns	CxSD = ns	

C, Cultivar; **SD,** sowing date: **CxSD,** cultivar interaction with sowing date; **Avg,** average: **LSD$_{T(0.05)}$,** least significant difference; ns: not significant. *Means with different small cap letters (a, b, and c) in the same column differ significantly from each other. **Means with different cap letters (A, B, and C) in the same row differ significantly from each other

Neck diameter

Neck diameter of cultivars significantly differed from each other in both seasons (Table 5). In 2009 'South Wester' plants produced bulbs with significantly thicker necks (22.55 mm) than plants from all the other cultivars. The thinnest necks (15.20 mm), produced by 'Charlize' was also significantly thinner than the bulb necks from 'Python' plants. Plants sown on 30 April produced bulbs with significantly thicker necks compared to those sown on 7 May. However, the necks of plants that were sown on 21 May did not differ significantly from those sown at the other 2 dates.

In 2010, 'Ceres Gold' plants produced significantly thicker necks (18.96 mm) than those of 'Python' (13.81 mm), 'Jaquar' (9.09 mm) and 'Charlize' (7.84 mm). Sowing date did not affect neck diameter at all during this year.

Different onion cultivars often differ with regard to neck size (Jilani and Ghaffoor, 2003). This was also observed in the present study in the 2 consecutive years (Table 5).

In both seasons plants of 'South Wester' and 'Ceres Gold', both mid intermediate cultivars, had thicker necks, followed by those of 'Python' and 'Jaquar', while plants from 'Charlize' had the thinnest necks.

The overall bulb neck diameters of the cultivars were much smaller in 2010 than in 2009. Bulbs with thinner necks originated from smaller plants due to a more dense plant population in 2010 than in 2009. Dawar et al. (2005) also reported that bulbs with thinner necks were obtained when plant population increased from 40 to 80 plants m^{-2}. Sowing date did not have such a pronounced effect on bulb neck diameter (Table 5), but the thinnest necks (17.61 cm) were obtained with the mid sowing date of 7 May in 2009 and the late sowing date of 8 June in 2010 (12.14 cm). Jilani (2004), reported that the thickest onion bulb necks was obtained with early plantings (27 October) compared to late plantings (26 December). Attainment of thinner neck with later planting is associated with small plants caused by earlier bulb initiation for late planted plants than for earlier plantings.

Bolting

Bolting percentages of onion were not statistically analysed. In 2009, 'South Wester' and 'Python' bolted whereas 'Charlize' and 'Jaquar' did not show any sign of bolting. No bolting occurred during 2010. With an early sowing of 'South Wester' (30 April), 30.30% of the plants bolted and as sowing date was delayed to 7 or 21 May, the percentage of bolters decreased to 24.24 and 18.18%, respectively. Only 12.12% of 'Python' plants bolted when sown on 30 April and none of the plants bolted when sown later. First incidences of bolting were noted on 'South Wester' and for 'Python' during early August in 2009 on plants sown on 30 April. Bolting of these cultivars were clearly influenced by temperature and cultivar. The minimum temperatures at the start of bolting ranged from -2.3 to 11.9°C. 'Python' and 'South Wester' sown on 30 April had reached the sensitive stage for bulbing (thermal time 600 degree days), but the occurrence of low temperatures may have been the reason for bolting. However, 'South Wester' sown on 7 May and 21 May had not yet reached the thermal time of 600 degree days (Table 5) when day length was sufficient for bulbing and started to bolt, thus indicating that 'South Wester' may be more susceptible to bolting (Van den Berg et al., 1997) than other cultivars.

Bulb shape

Jilani and Ghaffoor (2003) indicated that every cultivar has a typical bulb shape, which can be flattened, globular and spherical. Bulb shape in this study was visually determined. The results showed that sowing date did not affect bulb shape in any of the seasons. 'Charilze' produced globular bulbs, 'South Wester' round bulbs, 'Python' and 'Jaquar' top shaped bulbs, which were cultivar authentic. Grant and Carter (1994) stated that agronomic practices such as sowing date, plant population may affect bulb shape. They reported that if plant population increased from 50 to 100 plants m^{-2} and if sowing date was delayed from June to September, the bulbs became more oblate. This trend was not obtained in this study, possibly because of much lower plant populations (41 and 61 plants m^{-2} during 2009 and 2010, respectively).

Conclusion

This study emphasized that onion cultivars differed from each other due to their difference in genotype. Cultivars differed with respect to growth habit, bulb size, neck diameter and bolting. The different cultivars, however, did not differ in bulb fresh mass and yield. Although 'Python' was a more aggressive grower 'Jaquar' produced the heaviest bulbs and highest yields. Sowing date did not significantly influence plant growth. When sowing date was delayed in 2010 to the beginning of June bulb fresh mass and yield was significantly decreased. Bulb diameter also tended to decreased with a delayed planting date in 2010. In both seasons neck diameter also decreased with a delayed planting date. Planting date did not influence bulb shape at all. Cultivars tested in Bloemfontein (Free State Province) when all parameters are considered responded the best when sown from late April to late May, although the best results were obtained from sowing in May.

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