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Phenology of honeybush (*Cyclopia genistoides* and *C. subternata*) genotypes

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ABSTRACT

No information is available on the phenological phases between and within genotypes of *Cyclopia* (honeybush). This information is important to understand the timing of plant development and growth, species co-existence, and growth dynamics of the genus. The study spanning 2 years determined the monthly genotypic variation, the time of the start of a growth phase, and duration of budding, flowering, fruiting, and seed dispersal in *C. subternata* and *C. genistoides*. The results indicated differences in phenology between and within species and that initiation period among individuals of a phenological phase is inversely proportional to that duration of that phenophase. Budding, flowering, fruiting, and seed dispersal peaked in the months of July, September, October, and December, respectively. Compared to *C. genistoides*, *C. subternata* genotypes had a shorter time (days) from start of observation to start of flowering (25.9 versus 51.2), fruiting (46.1 versus 61.5), and seed dispersal (96.3 versus 110.0). However, the duration (days) of flowering (13.2 versus 24.3), fruiting (45.6 versus 52.2), and seed dispersal (4.3 versus 8.9) was shorter in *C. genistoides*. Using observational qualitative analysis, phenology of these *Cyclopia* species was categorised into three groups; early, intermediate, and late. The findings serve as a platform for investigating factors affecting the reproductive phases, morphology, and physiology in these and other *Cyclopia* species. It will assist farmers and researches to time crop requirements and management practices, thus having practical implications in the cultivation of the species.

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1. Introduction

Phenology is the study of the timing of plant growth phases that are biologically important, including the causes of timing and interrelation between growth phases of the same or different species (Ruml and Vulić, 2005). Phenological research assists in the monitoring of plant developmental stages during the growing season, understanding species interactions, and making comparable observations (Fenner, 1998; Saska and Kuzovkina, 2010). Apart from phenology being important in agricultural practices (Zavalloni et al., 2006; Saska and Kuzovkina, 2010), these growth phases may determine a species' ability to establish and persist in favourable and avoid unfavourable climatic conditions, thus shaping their distribution (Chuine, 2010; Van Der Putten et al., 2010; Pau et al., 2011; Gratani, 2014). Furthermore, phenology helps differentiate populations from different altitudes and latitudes (Vitasse et al., 2009), which may lead to variations in the morphological traits of widely distributed plant species, thus indicating survival ability and resource acquisition in heterogeneous and variable environments (Zhuang et al., 2011; Gratani, 2014). Species with wider geographical ranges can therefore exhibit a larger intraspecific variation in morphology, physiology, phenology, and growth rate (Gratani, 2014). In most cases, the timing of each phenological phase (phenophase) is regulated by mechanisms which act to ensure that each phase occurs in suitable conditions in its own period, although there is some interdependence between them. Phenological studies may include observation, recording, and interpretation of the timing of plants life history events (Fenner, 1998; Tooke and Battey, 2010; León-Ruiz et al., 2011).

Presently, information on the phenology of *Cyclopia* is scarce. *Cyclopia*, also known as "honeybush", is a largely unstudied leguminous genus of South African herbal teas restricted to the megadiverse Cape Floristic Region (Joubert et al., 2011). Many *Cyclopia* species (e.g. *C. genistoides*, *C. intermedia*, and *C. subternata*) flower in spring (September–October), although some species e.g. *C. sessiflora* flower in winter (May–June) (Van Der Walt, 2000; Stepanova et al., 2012). However, to date, no research has been conducted on the comparative phenology between and within *Cyclopia* species. Schröder et al. (2014) specified that plant phenophases can display inter-annual variability and large spatial differences attuned to environmental cues, individual characteristics such as genes, age, soil conditions, water supply, diseases, and competition. Phenological studies in ecosystems such as the Mediterranean climate of the Fynbos biome (Berjano et al., 2006) where *Cyclopia* naturally grows are important in order to identify

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phenological patterns (timing, frequency, and duration) within different areas. This paper assesses the phenophases of two commercially important *Cyclopia* species, namely, *C. genistoides* and *C. subternata*. The objective of the study was to determine the phenophases and the differences between and within these two *Cyclopia* genotypes in the Agriculture Research Council Infruitec-Nietvoorbij genebank collection. An understanding of the phenology of the two species will thus enhance farmers' ability to plan management practices in relation to the events occurring in the plant in order to schedule for pollination, irrigation, fertilisation, crop protection, harvesting, and other cultural practices at optimum times. In addition, this will assist in identifying suitable areas for commercial seed production purposes.

2. Materials and methods

2.1. Study populations

The study was carried out on 2-year-old plants, at Elsenburg Research Farm, situated in the Stellenbosch area of the Western Cape (S 33.502687, E 018.504760). Twenty-two *C. subternata* genotypes were replicated 60 times in a completely randomised block design, while 15 *C. genistoides* genotypes were replicated 90 times. However, mortality of cuttings resulted in a usable study population of approximately 651 and 156 individuals, respectively.

Clonal genotypes were selected and identified based on the area of collection (Fig. 1). *C. genistoides* genotypes were prefixed "G" denoting the species name, whereas *C. subternata* genotypes were prefixed "S". The subsequent alphabetical letter represented the site at which the genotype was initially collected before being rooted. *Cyclopia genistoides*, genotypes were collected from Gouriqau (GG) near Gouritsmond, Koksrivier (GK) near Pearly Beach and Toekomst (GT) near Bredasdorp. *Cyclopia subternata*, genotypes were collected from Tolbos (STB) near Napier, Kanetberg (SKB) near Barrydale, Groendal (SGD) near Loutewater, and Haarlem (SHL). Rooted cuttings of 12 months old were planted during 2011 in a sandy loam soil at a spacing for both species of 1 × 1 m (within rows and between rows). Both species where irrigated using drip irrigation in the dry summer seasons. No fertilisation or disease and pest control was applied since *Cyclopia* species are most frequently organically grown, and weeds were manually kept at minimal levels.

2.2. Sampling

Five randomly selected plants of each genotype were sampled. Where the number of plants was limited, other plants were sampled as in the case of STB101 (1), GG3 (3), GG34 (4), GK8 (2), and GG9 (1). To distinguish between plants and ensure correct data recording, sampled plants were marked with chevron tape. Data comprised weekly observation of plants using visual estimates of phenophases. Observations were scored on a 0–100 scale with 10 increments. The criterion applied in all the phenophases was a threshold value of 10% per individual plant modified from Pudas et al. (2008), where a 10% budding and 90% flowering meant that 10% of the buds on the individual plant had developed into flowers (90%) by the observation date. Data were collected in 2013 and 2014. The different stages within a phenophase were not recorded. Data from local weather stations' were used to describe the climate near the observed species, for both years and also that of the provenances where clones were initially collected (Table 1). Four phenophases were observed: budding, flowering, fruiting (pod formation), and seed dispersal (harvesting).

2.2.1. Budding phase

The budding phase was determined when buds visually appeared (Fig. 2A). Bud set was followed by the bud development phase characterised by swelling of buds (Fig. 2B) before bud maturation and where the bud was completely opened with petals still clustered together (Fig. 2C). The time to start of budding was not calculated because the study started after buds had already formed, especially in early genotypes. However, the duration of budding from first day of observation until first flowers appeared could be quantified.

2.2.2. Flowering phase

Flowering was defined as the stage when the reproductive parts (male stamen and female pistil) were visible between unfolded or open flower parts. This stage marked the period in which pollinators would be attracted, leading to pollen dispersal and thus pollination (Fig. 3A–C).

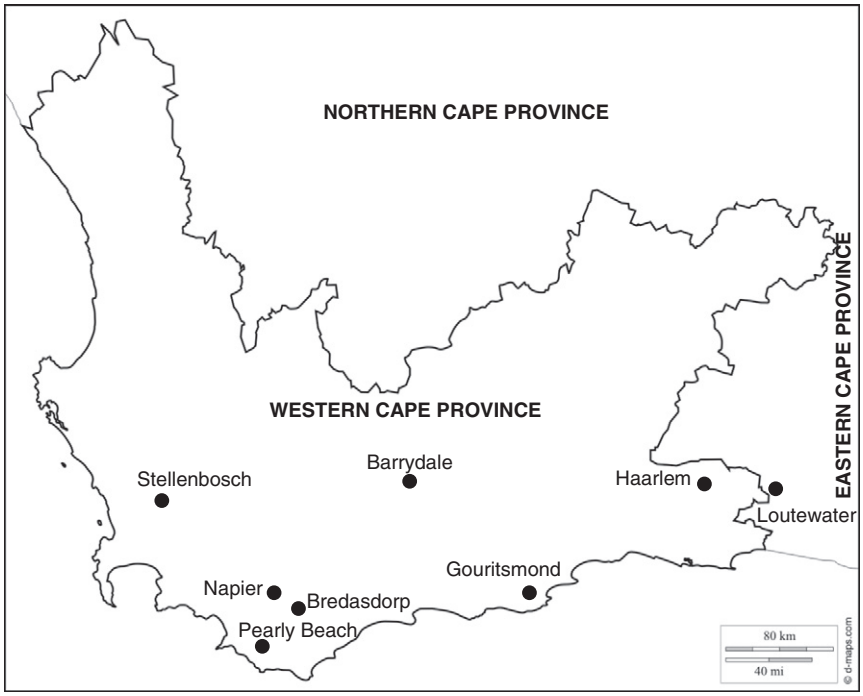

Fig. 1. Map of the geographical positions of the different *Cyclopia* species genotypes where they were initially collected before being grown in Elsenburg, Stellenbosch area, South Africa.

Table 1
Mean monthly climatic conditions for the Elsenburg site where all the *Cyclopia* species genotypes were monitored for their phenology in 2013 and 2014; and past 15 year mean climatic conditions for the weather stations closest to the geographical areas where clones of the different *Cyclopia* species were initially collected before being grown at Elsenburg.

Elsenburg Month	Minimum temperature (°C)		Maximum temperature (°C)		Rainfall (mm)	
	2013	2014	2013	2014	2013	2014
January	15.84	16.2	29.23	28.58	15.40	43.10
February	15.9	16.99	28.5	30.64	63.00	4.80
March	15.61	14.35	27.61	26.08	25.80	52.30
April	12.03	15.02	23.69	27.56	57.20	34.00
May	11.84	11.35	21.86	20.25	61.40	94.20
June	9.53	9.06	17.01	16.88	154.10	173.50
July	9.66	8.91	17.59	16.9	88.80	109.10
August	8.67	10.18	16.53	18.85	265.90	105.30
September	8.52	10.27	17.09	20.62	103.70	31.80
October	11.47	12.35	22.56	25.88	45.20	10.00
November	13.47	13.34	25.12	26.16	110.00	46.30
December	15.62	14.65	29.72	28.04	2.60	5.10
Mean	**12.35**	**12.72**	**23.04**	**23.87**	**82.76**	**59.13**

Weather station name	Genotype farm	Altitude (m)	Minimum temperature (°C)	Maximum temperature (°C)	Rainfall (mm)
Elsenburg	All	227.00	12.32	23.45	720.58
Riversdale – UITKYK	Kanetberg (SKB)	156.00	10.88	22.94	436.03
Mosselbaai – Patrysfontein	Gouriqau (GG)	203.00	11.41	22.17	655.18
Overstand: Agulhas National Park	Koksrivier and Toekomst (GK and GT)	39.00	11.69	22.38	537.83
Joubertina: Misgund	Haarlem and Groendal (SHL and SGD)	746.00	6.84	21.83	640.46
Jonaskraal	Tolsbos (STB)	106.00	10.28	23.46	431.61

GG—*C. genistoides* clones collected from the Gouriqua area.
GK—*C. genistoides* clones collected from the Koksrivier area.
GT—*C. genistoides* clones collected from the Toekomst area.
SKB—*C. subternata* clones collected from Kanetberg area.
SGD—*C. subternata* clones collected from the Groendal area.
SHL—*C. subternata* clones collected from the Haarlem area.
STB—*C. subternata* clones collected from the Tolbos area.

2.2.3. Fruiting and seed dispersal phase

In *Cyclopia*, the flower opening period is terminated by petal withering or abscission, which coincides with formation of pods (Fig. 4A). This marks the start of the fruiting phase which is characterised by the remnants of the stigma and style still being attached to the young pod, which then increases in size, length, and width (Fig. 4B–C). Thereafter, the developing pod swells as a result of differential growth of different tissues (Setia et al., 1987) (Fig. 4D). At the end of this stage, the pod matures by changing in colour from grey to brown (Fig. 4E). This signals the beginning of seed dispersal (harvesting period) so as to avoid pod splitting and dispersal of seeds. Harvesting was defined as the stage when the fruit (pods) reached maximum size (fully swollen) and changed to a reddish-brown colour, and continued until all pods were eventually harvested (Fig. 4F).

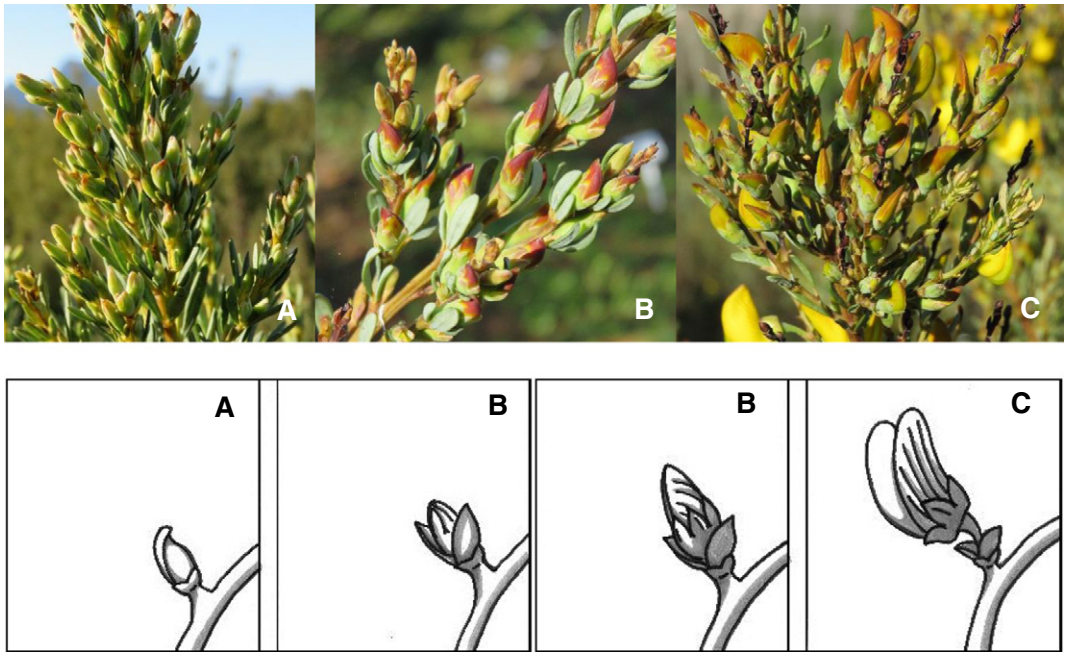

Fig. 2. Observation of budding phase of *Cyclopia* species (A) bud set, (B) bud development and swelling, and (C) bud maturation.

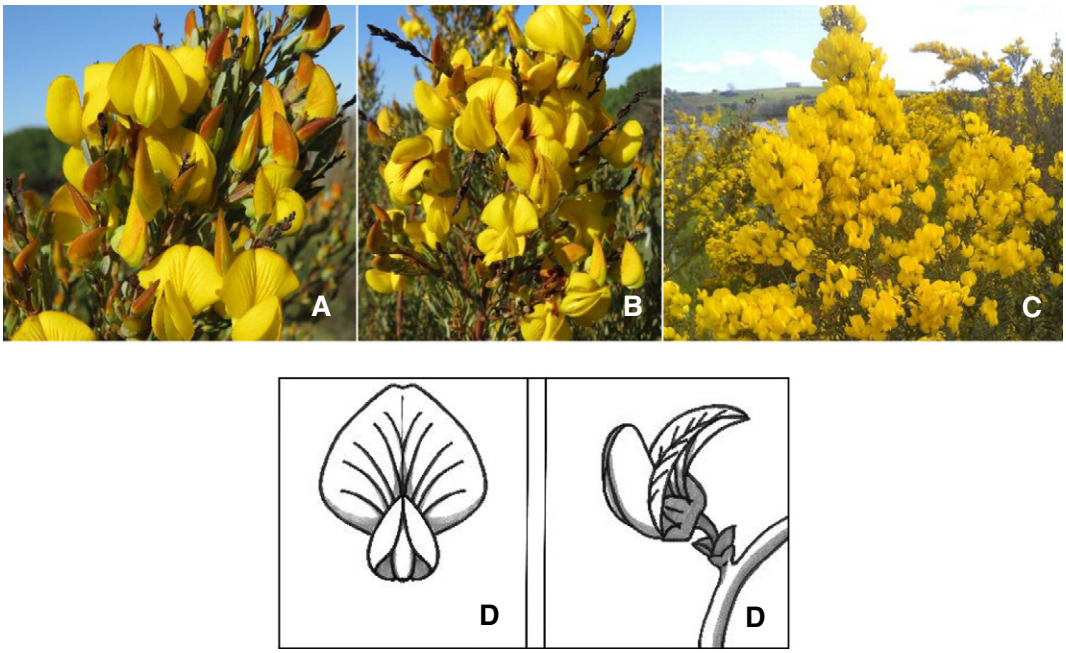

Fig. 3. Observation of flowering phase of *Cyclopia* species (A) early flower opening when few flowers open on an inflorescence, (B) increases in flower setting (C), inflorescence in full flowering, and D) front and side view of a fully opened flower.

2.3. Statistical analysis

An analysis of variance (ANOVA) (Snedecor and Cochran, 1967) was carried out to determine the genotypic variation in the occurrence of phenophases (%) according to the month of observation, the mean time to the start of each phenophase; and duration of each phenophase: flowering, fruiting, and seed dispersal. Fisher's least significant (LSD) test (Montgomery, 2005) was used to compare group means for the interaction between species genotype and month of observation of the observed phenophases. The test was conducted at a nominal significance level of $p = 0.05$. All analyses were carried out in the statistical software package SAS 9.2 (SAS Institute, 2012). The PROC GLM function in this software was used to perform the ANOVA as well as the Fisher's LSD test. The standardised residuals were tested for normality using the Shapiro–Wilk test (Snedecor and Cochran, 1967).

The time of the start and duration of each phenophase are shown in Tables 2 and 3 for the two species. Time to start was calculated by subtracting the time taken to the start of each phenophase (flowering, fruiting, and seed dispersal) of each genotype plant from the first day of field observation. Phenophase duration was calculated by the number of days from the start of each phenophase up until the last day of observation for that phase. Grouping of genotypes according to phenophase pattern in Table 4 was based on ANOVA analysis of time to the start of each phenophase per genotype. The data used here were grouped according to the following criteria: 1) early—genotypes with shorter phenophase, 2) intermediate—genotypes with transitional development, and 3) late—genotypes with longer phenophase.

3. Results

3.1. Genotypic variation in phenophases in Cyclopia according to month of observation

3.1.1. Cyclopia genistoides

3.1.1.1. Budding phase. Mean budding percentage of *C. genistoides* genotypes was significantly higher ($p < 0.0001$) during July (98%) and August (100.0%) compared to September (61.1%) and October (2.3%) (Fig. 5A). However, budding of GG31, GK1, GK2, GK3, GK4, GK5, GK6, GK7, and GT2 were significantly higher (68.0–100.0%) in September compared to other genotypes. Budding remained significantly higher between July to September for GK1, GK2, and GK4 compared to all other genotypes.

3.1.1.2. Flowering phase. Mean flowering percentage of *C. genistoides* was concentrated between September and October, peaking ($p < 0.0001$) in September (28.4%) compared to October (19.0%). Flowering was significantly higher ($p < 0.0001$) in September for GG3 (65.0%), GG53 (62.0%), GT1 (58.0%), and GG9 (52.5%), while was delayed in October for GK2 (36.0%), GK1 (35.2%), GK4 (34.4%), GG31 (31.6%), and GT2 (27.2%) as depicted in Fig. 5B.

3.1.1.3. Fruiting phase (pod development). Fruiting in *C. genistoides* started in September extending to November, and peaking in October (76.2%), being significantly higher ($p < 0.0001$) than the values recorded in September (9.3%) and November (53.5%). Fruiting, however, peaked in September for GK8 (62.5%), GG9 (47.5%), GG3 (32.5%), GT1 (28%), and GG34 (23.8%), while peaking ($p < 0.0001$) in November for GK1 (100.0%), GK2 (75.0%), GK4 (80.5%), and GT2 (85.0%) (Fig. 5C).

3.1.1.4. Seed dispersal phase. Seed release from pods in *C. genistoides* started in November and ended in December when all genotypes had been harvested. Approximately 43.5% of *C. genistoides* genotypes were harvested in November compared to the 100.0% in December. Seed dispersal (harvesting) significantly peaked ($p < 0.0001$) in November for GG9 (100.0%), GG3 (97.5%), GK8 (97.5%), and GG9 (100.0%) GT1 (78%) and GG34 (68.8%) compared to all other genotypes (Fig. 5D).

3.1.2. Cyclopia subternata

3.1.2.1. Budding phase. Mean budding percentage of *C. subternata* peaked ($p < 0.0001$) in July (97.8%) relative to August (78.0%) and September (5.6%) (Fig. 6A). In July, budding of 94.0–100.0% was observed in 19 of the 22 *C. subternata* genotypes. Budding of SKB4 (100.0%) and STB101 (87.5%) significantly peaked ($p < 0.0001$) in August, while in SKB3, SKB15, SKB18, STB102, and STB103, budding was extended from July to August.

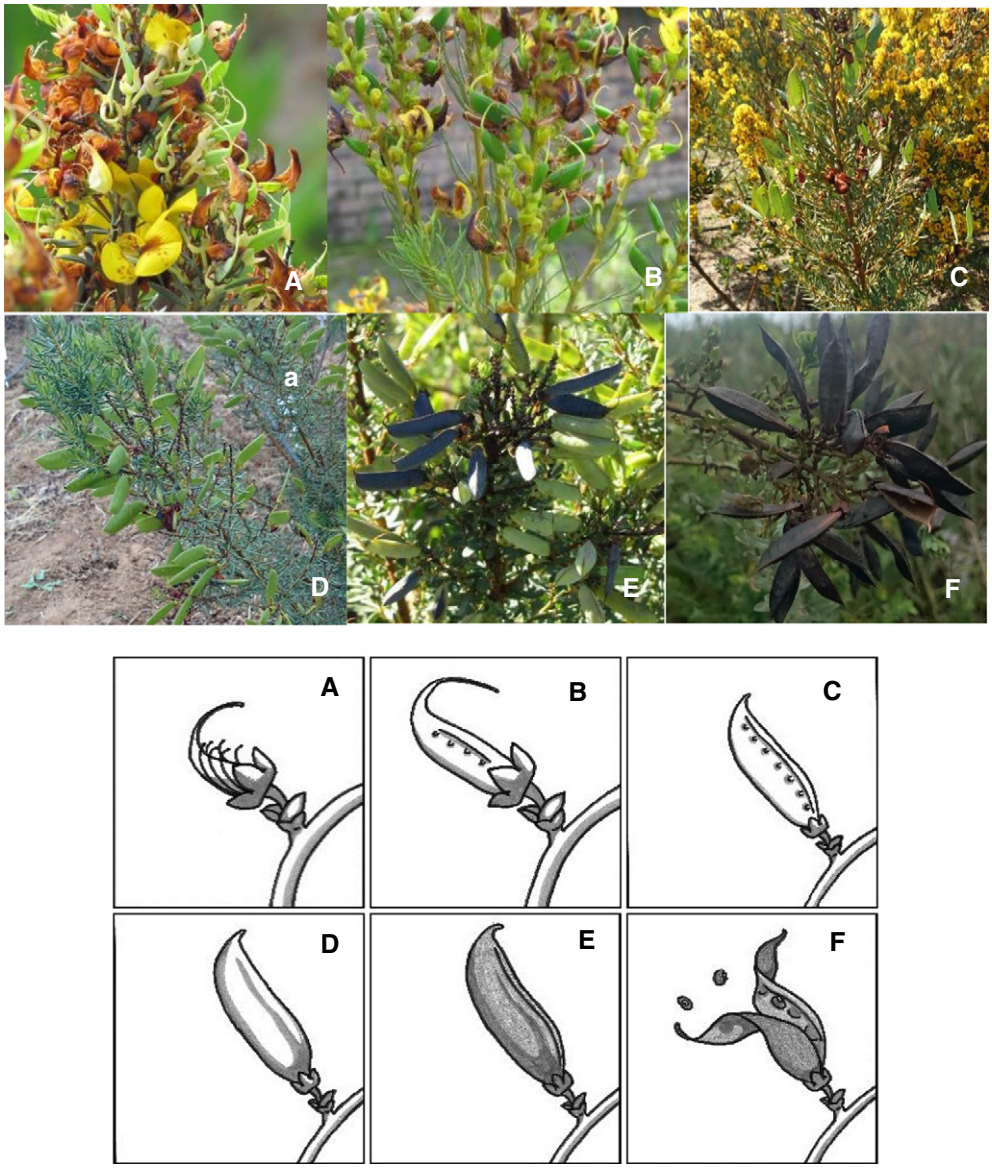

Fig. 4. Observation of fruiting to seed dispersal phase of *Cyclopia* species (A) fruit set, (B–C) growth and development of pods, (D) inflation of pods, (E) pod maturation associated with pod colour changes, and (F) pods ready for harvesting or seed dispersal.

3.1.2.2. Flowering phase. Mean flowering of *C. subternata* genotypes peaked ($p < 0.0001$) in September (53.5%) compared to August (21.9%) and October (0.36%) (Fig. 6B). Flowering significantly peaked ($p < 0.0001$) in August only for SGD6 (60.0%), SKB13 (45.5%), SKB11 (45.0%), STB1 (45.0%), SGD9 (43.0%), SKB6 (41.0%), and SHL2 (36.0%) compared to all other genotypes.

3.1.2.3. Fruiting phase. A significantly higher ($p < 0.0001$) number of pods in *C. subternata* were observed in October (92.3%) than in September (41.0%) and November (21.0%). However, fruiting of 9 of the 22 genotypes peaked ($p < 0.0001$) in September; SGD6 (74.0%), SKB11 (62.5%), SKB13 (61.0%), STB1 (56.5%), SKB6 (55.0%), SHL2 (54.5%), SGD7 (49.5%), SGD1 (49.5%), and SKB14 (48.1%) (Fig. 6C). Fruiting of SGD6 did not differ between September (74.0%) and October (66.8%), although SGD6 was significantly higher than in all other genotypes.

3.1.2.4. Seed dispersal phase. Seed release from pods in *C. subternata* commenced in October (6.4%) and increased to 79.2% by November, and by December all genotypes had been harvested (100%) (Fig. 6D). Seed dispersal was started in October for SGD6 (33.2%), SHL2 (17.6%), SKB13 (13.2%), SGD1 (11.6%), and SHL3 (11.6%), peaking ($p < 0.0001$) in November (90.0–100.0%) compared to all other genotypes.

3.2. Genotypic variation in time taken to start and duration of phenophases of Cyclopia

3.2.1. Cyclopia genistoides

3.2.1.1. Budding phase. Mean budding of *C. genistoides* genotypes lasted 46.4 days. Budding was significantly shorter ($p < 0.0001$) in four genotypes: GG9 (30.0 days), GK8 (30.0 days), GT1 (35.0 days), and GG3 (35.0 days) compared to other genotypes (Table 2). However, there were no significant differences in budding of GG3 and GT1 relative to GG53 (40.6 days) and GG34 (42.5 days), while was significantly extended in GK4 (60.6 days), GK1 (58.2 days), GK2 (57.8 days), GT2 (57.4 days), GG31 (54.4 days), and GK3 (49.8 days).

3.2.1.2. Flowering phase. The mean time to start of flowering in *C. genistoides* was 51.2 days, although mean flowering duration lasted approximately 13.2 days. The mean time to start of flowering was

Table 2
Mean time to start and duration (days) of phenophases of *Cyclopia genistoides* genotypes. In brackets are the standard errors of the respective means.

Genotype	Budding	Flowering		Fruiting		Seed dispersal	
	duration	Time to start	Duration	Time to start	Duration	Time to start	Duration
GG9	30.0_{e} (±0.000)	35.0_{b} (±0.000)	13.0_{b} (±0.000)	42.0_{g} (±0.000)	51.0_{abc} (±0.000)	98.0_{f} (±0.000)	0.0_{c} (±0.000)
GK8	30.0_{e} (±0.000)	35.0_{b} (±0.000)	10.0_{b} (±3.000)	42.0_{g} (±0.000)	56.0_{a} (±0.000)	98.0_{f} (±0.000)	7.0_{abc} (±0.000)
GG3	35.0_{de} (±0.000)	35.0_{b} (±0.000)	13.0_{b} (±0.000)	46.0_{fg} (±2.000)	52.0_{ab} (±2.00)	98.0_{f} (±0.000)	7.0_{abc} (±0.000)
GT1	35.0_{de} (±0.000)	35.0_{b} (±0.000)	13.0_{b} (±0.000)	49.8_{efg} (±1.800)	47.2_{bcd} (±1.828)	99.4_{ef} (±1.400)	5.6_{abc} (±1.400)
GG53	40.6_{cde} (±1.400)	42.0_{b} (±0.000)	21.0_{a} (±0.000)	60.8_{cde} (±2.577)	45.6_{bcd} (±1.470)	105.0_{def} (±0.000)	8.0_{ab} (±1.000)
GG34	42.5_{cd} (±6.144)	46.0_{b} (±6.351)	11.3_{b} (±1.750)	56.0_{def} (±8.083)	44.8_{cd} (±3.881)	106.3_{def} (±4.871)	0.0_{c} (±0.000)
GK5	48.0_{bc} (±0.000)	49.8_{b} (±1.800)	13.2_{b} (±1.800)	68.6_{abc} (±1.400)	42.0_{d} (±2.214)	113.0_{bcd} (±1.000)	4.0_{abc} (±1.000)
GK6	48.0_{bc} (±0.000)	51.6_{b} (±2.205)	14.2_{b} (±2.557)	67.2_{abcd} (±1.715)	44.8_{cd} (±1.715)	112.0_{cd} (±0.000)	5.0_{abc} (±0.000)
GK7	48.0_{bc} (±0.000)	48.0_{b} (±0.000)	15.0_{ab} (±0.000)	63.0_{bcd} (±0.000)	42.0_{d} (±0.000)	107.8_{de} (±1.715)	4.2_{abc} (±1.715)
GK3	49.8_{abc} ((±1.800)	49.8_{b} (±1.800)	14.6_{b} (±0.400)	64.4_{bcd} (±1.400)	42.0_{d} (±0.000)	112.0_{cd} (±0.000)	1.0_{bc} (±1.000)
GG31	54.4_{ab} (±5.653)	57.6_{b} (±4.069)	11.6_{b} (±3.655)	69.0_{abc} (±9.000)	43.3_{d} (±4.250)	113.4_{bcd} (±3.429)	8.4_{a} (±3.429)
GT2	57.4_{ab} (±5.600)	98.4_{a} (±36.918)	11.0_{b} (±1.673)	70.4_{abc} (±5.810)	42.8_{d} (±2.375)	121.8_{ab} (±4.200)	0.0_{c} (±0.000)
GK2	57.8_{ab} (±7.081)	68.3_{ab} (±1.750)	11.5_{b} (±2.021)	78.0_{a} (±0.000)	42.0_{d} (±3.000)	121.3_{abc} (±7.273)	6.5_{abc} (±6.500)
GK1	58.2_{ab} (±1.200)	59.6_{b} (±2.600)	12.0_{b} (±1.000)	71.6_{abc} (±1.600)	45.4_{bcd} (±1.600)	126.0_{a} (±0.000)	0.0_{c} (±0.000)
GK4	60.6_{a} (±1.470)	57.0_{b} (±0.000)	13.2_{b} (±2.375)	73.2_{ab} (±1.960)	43.8_{d} (±1.960)	118.6_{abc} (±3.156)	7.4_{ab} (±3.156)
Mean	**46.4**	**51.2**	**13.2**	**61.5**	**45.6**	**110.0**	**4.3**

Different letters indicate significant differences at $p = 0.05$.
GG—*C. genistoides* clones collected from the Gouriqua area.
GK—*C. genistoides* clones collected from the Koksrivier area.
GT—*C. genistoides* clones collected from the Toekomst area.

increased ($p = 0.0382$) to 35.0 days for GG9, GK8, GG3, and GT1 compared to GT2 (98.4 days) (Table 2). Although start of flowering was significantly delayed for GT2, it did not differ significantly to GK2 (68.3 days). Mean flowering duration lasted 10–15 days for a majority of the genotypes. However, GG53 (21.0 days) had a significantly longer ($p = 0.0423$) duration compared to the other genotypes, although GG53 did not differ significantly to GK7 (15.0 days).

3.2.1.3. Fruiting phase. Fruiting in *C. genistoides* started after 61.5 days and lasted 45.6 days. Fruiting started earlier ($p < 0.0001$) in GG9 (42.0 days), GK8 (42.0 days), GG3 (46.0 days), and GT1 (49.8 days) (Table 2). However, start of fruiting for GT1 was not significantly different to GG34 (56 days) and GG53 (60.8 days). Start of fruiting in GK2 was delayed to 78.0 days, although did not differ significantly to GK4 (73.2 days), GK1 (71.6 days), GT2 (70.4 days), GG31 (69.0 days), GK5 (68.6 days), and GK6 (67.2 days). Comparable to the fruiting duration of 51.0–56.0 days in GG9, GG3, and GK8, fruiting was significantly shorter ($p = 0.0203$) (42.0–43.8 days) in GK2, GK5, GK7, GK3, GT2, GG31, and GK4. No significant differences were however observed between fruiting of GG3 (52.0 days), GG9 (51.0 days), GT1 (days), GG53 (45.6 days), and GK1 (45.4 days).

3.2.1.4. Seed dispersal phase. Seed release from pods in *C. genistoides* was started after 110.0 days and lasted 4.3 days. Seed dispersal started earlier ($p < 0.0001$) for GG9 (98.0 days), GK8 (98.0 days), GG3 (98.0 days), GT1 (99.4 days), GG53 (105.0 days), and GG34 (106.3 days) as

Table 3
Mean time to start and duration (days) of phenophases of *Cyclopia subternata* genotypes. In brackets are the standard errors of the respective means.

	Budding	Flowering		Fruiting		Seed dispersal	
Genotype	Duration	Time to start	Duration	Time to start	Duration	Time to start	Duration
SGD6	14.0_{g} (±0.000)	4.6_{e} (±2.926)	33.2_{ab} (±1.356)	42.0_{d} (±0.000)	43.0_{gh} (±0.000)	85.0_{f} (±0.000)	8.0_{abcd} (±0.000)
SGD7	30.0_{f} (±0.000)	21.2_{d} (±1.800)	26.8_{bcd} (±1.800)	42.0_{d} (±0.000)	63.0_{a} (±0.000)	99.2_{abcd} (±3.955)	12.8_{ab} (±3.955)
SHL2	30.0_{f} (±0.000)	20.2_{d} (±2.800)	27.8_{bc} (±2.800)	42.0_{d} (±0.000)	53.0_{bcdef} (±1.225)	93.0_{de} (±0.000)	7.8_{abcd} (±1.715)
SKB11	30.0_{f} (±0.000)	19.4_{d} (±2.205)	25.0_{cde} (±1.643)	42.0_{d} (±0.000)	57.8_{ab} (±2.311)	97.4_{cde} (±2.205)	9.0_{abcd} (±1.703)
SKB13	30.0_{f} (±0.000)	17.6_{d} (±2.205)	36.8_{a} (±6.192)	42.0_{d} (±0.000)	54.0_{bcde} (±1.225)	91.4_{ef} (±1.600)	10.8_{abc} (±2.782)
STB1	30.0_{f} (±0.000)	23.0_{cd} (±0.000)	25.0_{cde} (±0.000)	42.0_{d} (±0.000)	56.8_{abc} (±2.691)	$95.0d_{e}$ (±1.225)	10.0_{abc} (±2.074)
SGD2	31.0_{ef} (±1.000)	23.0_{cd} (±0.000)	25.0_{cde} (±0.000)	46.8_{bc} (±1.200)	54.0_{bcde} (±1.643)	105.4_{a} (±3.473)	2.4_{de} (±2.400)
SHL3	31.0_{ef} (±1.000)	23.0_{cd} (±0.000)	25.0_{cde} (±0.000)	46.8_{bc} (±1.200)	50.2_{cdef} (±1.744)	93.0_{de} (±0.000)	10.6_{abc} (±1.400)
SKB14	32.0_{de} (±1.225)	23.0_{cd} (±0.000)	21.4_{cdef} (±3.600)	42.0_{d} (±0.000)	56.0_{bcd} (±0.000)	93.0_{de} (±0.000)	12.0_{ab} (±0.000)
SGD1	33.0_{cd} (±1.225)	23.0_{cd} (±0.000)	25.0_{cde} (±0.000)	43.2_{d} (±1.200)	57.6_{ab} (±2.462)	95.2_{de} (±4.477)	12.6_{ab} (±3.572)
SKB5	34.0_{bc} (±1.000)	34.4_{ab} (±4.654)	22.0_{cdef} (±3.550)	54.0_{a} (±3.000)	48.2_{efg} (±2.375)	97.8_{bcde} (±2.939)	11.4_{ab} (±3.641)
SKB6	34.0_{bc} (±1.000)	19.4_{d} (±2.205)	27.4_{bc} (±1.749)	42.0_{d} (±0.000)	56.0_{bcd} (±0000)	93.0_{de} (±0.000)	12.0_{ab}(±0.000)
SKB7	34.0_{bc} (±1.000)	39.4_{a} (±13.254)	18.4_{ef} (±3.341)	46.8_{bc} (±1.200)	50.0_{def} (±2.214)	93.0_{de} (±0.000)	11.0_{abc} (±3.066)
SGD3	35.0_{b} (±0.000)	23.0_{cd} (±0.000)	25.0_{cde} (±0.000)	44.4_{cd} (±1.470)	46.6_{fgh} (±6.539)	96.0_{cde} (±2.683)	9.0_{abcd} (±3.000)
SGD9	35.0_{b} (±0.000)	23.0_{cd} (±0.000)	25.0_{cde} (±0.000)	42.0_{d} (±0.000)	56.0_{bcd} (±0.000)	93.0_{de} (±0.000)	12.0_{ab} (±0.000)
SKB3	35.0_{b} (±0.000)	27.8_{bcd} (±2.939)	22.0_{cdef} (±4.025)	49.8_{b} (±1.800)	52.4_{bcdef} (±3.156)	105.4_{a} (±3.473)	3.8_{cde} (±2.458)
SKB4	35.0_{b} (±0.000)	37.8_{ab} (±1.715)	19.2_{def} (±1.715)	49.8_{b} (±1.800)	49.6_{defg} (±0.400)	102.6_{abc} (±2.400)	3.8_{abc} (±2.458)
SKB15	35.0_{b} (±0.000)	32.6_{abc} (±2.400)	22.6_{cdef} (±3.341)	48.0_{b} (±0.000)	54.2_{bcde} (±1.715)	94.0_{de} (±1.000)	15.2_{a} (±2.458)
SKB18	35.0_{b} (±0.000)	27.8_{bcd} (±2.939)	20.2_{cdef} (±2.939)	44.4_{cd} (±1.470)	53.6_{bcde} (±1.470)	97.8_{bcde} (±2.939)	7.2_{bcde} (±2.939)
STB102	35.0_{b} (±0.000)	40.6_{a} (±1.400)	21.2_{cdef} (±2.059)	57.0_{a} (±0.000)	41.0_{h} (±0.000)	97.8_{bcde} (±2.939)	7.2_{bcde} (±2.939)
STB103	35.0_{b} (±0.000)	23.0_{cd} (±0.000)	25.0_{cde} (±0.000)	42.0_{d} (±0.000)	55.0_{bcd} (±1.000)	95.4_{cde} (±2.400)	8.2_{abcd} (±2.458)
STB101	42.0_{a} (±0.000)	42.0_{a} (±0.000)	15.0_{f} (±0.000)	57.0_{a} (±0.000)	41.0_{h} (±0.000)	105.0_{ab} (±0.000)	0.0_{e} (±0.000)
Mean	**32.5**	**25.9**	**24.3**	**46.1**	**52.2**	**96.3**	**8.9**

Different letters indicate significant differences at $p = 0.05$.
SKB—*C. subternata* clones collected from Kanetberg area.
SGD—*C. subternata* clones collected from the Groendal area.
SHL—*C. subternata* clones collected from the Haarlem area.
STB—*C. subternata* clones collected from the Tolbos area.

Table 4
Summarised phenophases of *Cyclopia* species (clonal genotypes of *C. genistoides* and *C. subternata*).

Phenophases								
Flowering			Fruiting			Seed dispersal		
Early	Inter	Late	Early	Inter	Late	Early	Inter	Late
GG3	GG34	GG31	GG3	GG31	GK1	GG3	GG31	GK1
GG53	GK3	GK1	GG34	GG53	GK2	GG34	GG53	GK2
GG9	GK5	GK2	GG9	GK3	GK4	GG9	GK3	GK4
GT1	GK6	GK4	GK8	GK5	GT2	GK8	GK5	GT2
SKB6	GK7	GT2	GT1	GK6	SKB5	GT1	GK6	SKB3
SKB11	SGD3	SKB4	SKB6	GK7	STB101	SGD6	GK7	STB101
SKB13	SKB14	SKB5	SKB11	SKB7	STB102	SKB13	SKB5	SGD2
SGD6	SGD1	SKB7	SKB13	SHL3			SKB7	SKB4
SGD7	SGD7	SKB15	SKB14	SKB15			SKB18	
SHL2	STB103	STB101	SHL2	SKB18			SGD3	
	SKB3	STB102	SGD1	SKB3			SGD9	
	SGD2		SGD6	SKB4			SKB14	
	SHL3		SGD7	SGD3			SHL2	
	SKB18		SGD9	SGD2			SHL3	
	STB1		STB1				SGD1	
			STB103				STB1	
							SKB6	
							SKB11	
							SKB15	
							SGD7	
							STB102	
							STB103	

GG—*C. genistoides* clones collected from the Gouriqua area.
GK—*C. genistoides* clones collected from the Koksrivier area.
GT—*C. genistoides* clones collected from the Toekomst area.
SKB—*C. subternata* clones collected from Kanetberg area.
SGD—*C. subternata* clones collected from the Groendal area.
SHL—*C. subternata* clones collected from the Haarlem area.
STB—*C. subternata* clones collected from the Tolbos area.
Early—genotypes with observed shorter period to start of phenophase.
Inter—genotypes with observed transitional period to start of phenophase.
Late—genotypes with observed longer period to start of phenophase.

shown in Table 2. Seed release was delayed to 126.0 days in GK1, although did not differ significantly to GT2 (121.8 days), GK2 (121.3 days), and GK4 (118.6 days). Duration of seed dispersal was shorter ($p = 0488$) for GG9, GG34, GT2, GK3, and GK1 being approximately 1.0 day compared to GG31 (8.4 days). Seed dispersal although was extended for GG31, did not differ significantly to GG53 (8.0 days), GK4 (7.4 days), GK8 (7.0 days), GG3 (7.0 days), GK2 (6.5 days), GT1 (5.6 days), GK6 (5.0 days), GK7 (4.2 days), and GK5 (4.0 days).

3.2.2. *Cyclopia subternata*

3.2.2.1. Budding phase. The budding duration for *C. subternata* genotypes lasted 32.5 days. Budding was shorter ($p < 0.0001$) for SGD6 (14.0 days) compared to other genotypes. Budding was significantly extended in STB101 (42.0 days) compared to other genotypes. Mean budding of all other genotypes was generally between 30.0 and 35.0 days, although significant differences between genotypes were observed (Table 3).

3.2.2.2. Flowering phase. Generally, flowering in *C. subternata* started after 25.9 days and lasted 24.3 days. However, flowering was earlier ($p < 0.0001$) for SGD6 (4.6 days) compared to other genotypes (Table 3). In contrast, start of flowering was delayed in STB101 (42.0 days), STB102 (40.6 days), SKB7 (39.4 days), SKB4 (37.8 days), SKB5 (34.4 days), and SKB15 (32.6 days). Duration of flowering was shorter ($p = 0.0004$) in STB101 (15.0days) compared to the other thirteen genotypes, apart from SKB7 (18.4 days), SKB4 (19.2 days), SKB18 (20.2 days), STB102 (21.2 days), SKB14 (21.4 days), SKB3 (22.0 days), SKB5 (22.0 days), and SKB15 (22.6 days). Flowering duration was extended in SKB13 (36.8 days) and SGD6 (33.2 days) compared to other genotypes.

3.2.2.3. Fruiting phase. The mean time to start and duration of fruiting of *C. subternata* genotypes was 46.1 and 52.5 days, respectively. Fruiting was earlier ($p < 0.0001$) (42.0–44.4 days) for 13 of the 22 genotypes

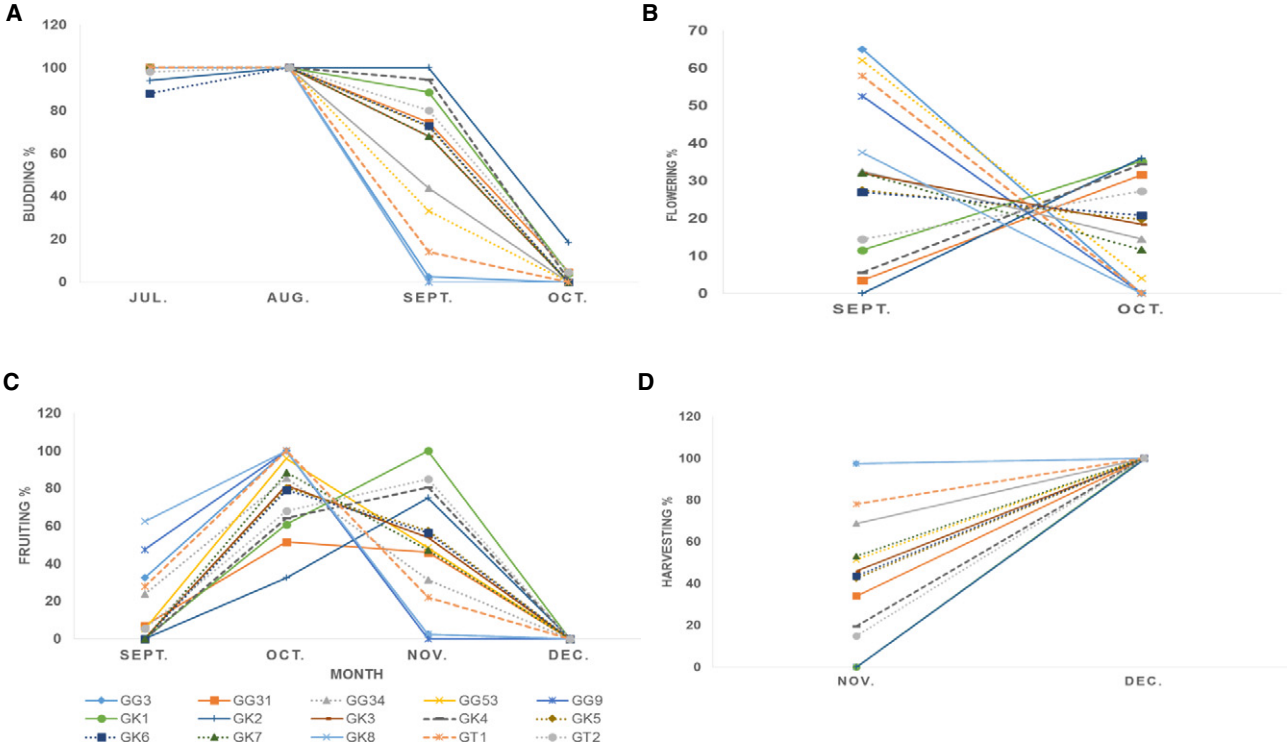

Fig. 5. The mean percentage of (A) budding, (B) flowering, (C) fruiting, and (D) seed dispersal (harvesting) in *C. genistoides* genotypes according to the month of observation at the Elsenburg research farm. GG—*C. genistoides* clones collected from the Gouriqua area; GK—*C. genistoides* clones collected from the Koksrivier area and GT—*C. genistoides* clones collected from the Toekomst area.

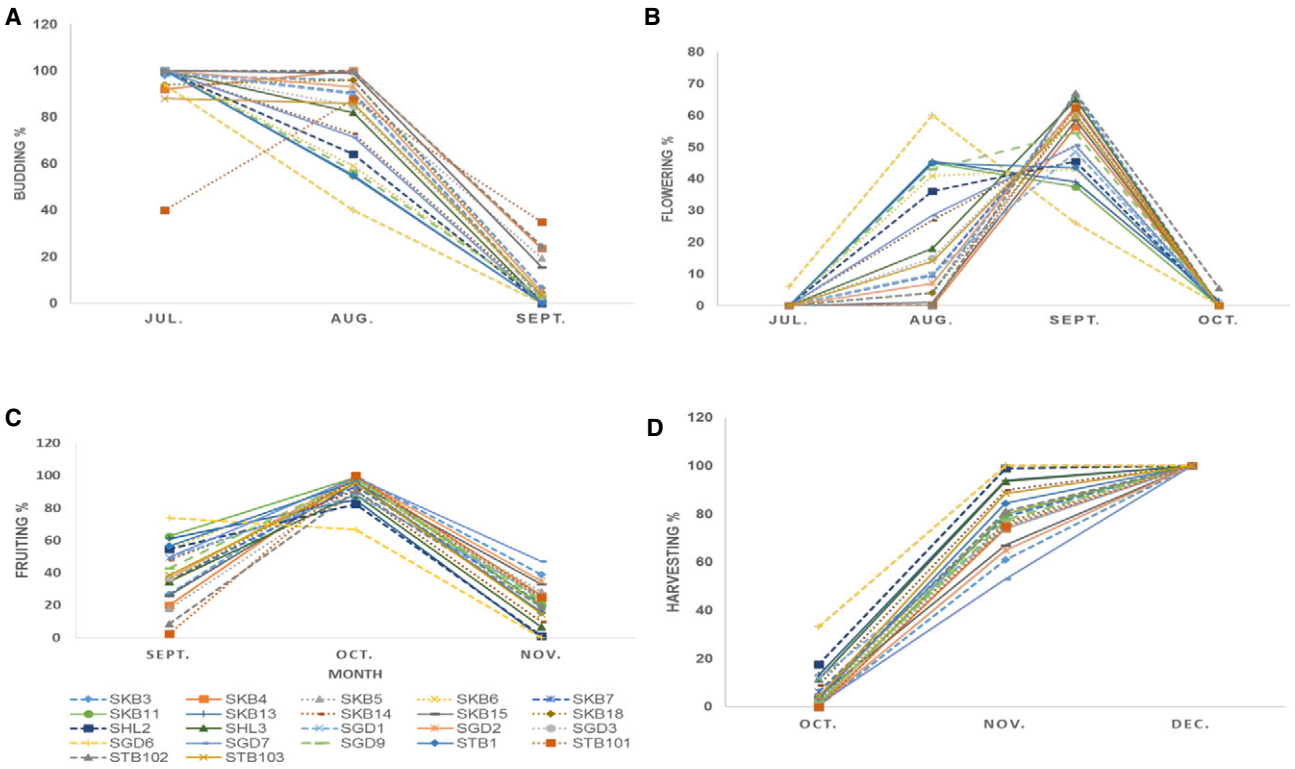

Fig. 6. The mean percentage of (A) budding, (B) flowering, (C) fruiting, and (D) seed dispersal (harvesting) in *C. subternata* genotypes according to the month of observation at the Elsenburg research farm. SKB—*C. subternata* clones collected from Kanetberg area, SGD—*C. subternata* clones collected from the Groendal area, SHL—*C. subternata* clones collected from the Haarlem area, and STB—*C. subternata* clones collected from the Tolbos area.

studied (Table 3). Start of fruiting was significantly delayed in STB101 (57.0 days), STB102 (57.0 days), and SKB5 (54.0 days) compared to other genotypes. Start of fruiting for the remaining six genotypes was 46.8–49.8 days; this being SGD2, SHL3, SKB7, SKB3, SKB4, and SKB15. Fruiting duration was shorter ($p < 0.0001$) for STB101 and STB102 being 41.0 days compared to the other eighteen genotypes, but did not differ significantly to SGD6 (43.0 days) and SGD3 (46.6 days). Fruiting was extended in SGD7 (63.0 days), SKB11 (57.8 days), SGD1 (57.6 days), and STB1 (56.8 days), with that of the remaining twelve genotypes between 50.0 and 56.0 days.

3.2.2.4. Seed dispersal phase. Seed release from pods in *C. subternata* genotypes was started after 96.3 days and lasted 8.9 days. However, seed dispersal started earlier ($p < 0.0001$) for SGD6 (85.0 days) and SKB13 (91.4 days) as indicated in Table 3. Start of seed dispersal was, however, delayed in SGD2 (105.4 days), SKB3 (105.4 days), STB101 (105.0 days), and SKB4 (102.6 days). Time to start of seed dispersal in SKB13 (91.4 days) did not differ significantly to the remaining 15 genotypes which ranged between 93.0 and 99.2 days. Seed release duration in STB101 (0.0 days) significantly differed ($p = 0.0302$) to the other sixteen genotypes (7.8–15.2 days), but did not differ significantly to SGD2 (2.4 days), SKB3 (3.8 days), SKB4 (3.8 days), SKB18 (7.2 days), and STB102 (7.2 days).

The phenophases of the *Cyclopia* genotypes were determined using the mean start time (days) from the first field observation day. Using the observational qualitative analysis, phenology of the *Cyclopia* species can be categorised into three groups; early, intermediate and late genotypes, with start time and duration of each phenophase as summarised in Table 4. Mean start time for each genotype phenophase was determined for flowering, fruiting, and seed dispersal. Start time for budding phenology was, however, not determined due to the visibility of buds on the individual plants already when the study was initiated.

4. Discussion

Generally, the studied phenophases: budding, flowering, fruiting, and seed dispersal of the *Cyclopia* species peaked in the months of July, September, October, and December, respectively. However, the peak of budding in *C. genistoides* extended to August. In *C. subternata*, flowering, fruiting, and seed dispersal started 1st week of August, 1st week of September, and 4th week of October, extending to 1st week of November, mid-November and mid-December, respectively. In contrast, flowering, fruiting, and seed dispersal in *C. genistoides* started last week of August, mid-September, and 1st week of November, extending to end of October, 1st week of November, and last week of December, respectively. Interpretation of the *Cyclopia* phenology variation among and within species poses a challenge since these species and factors known to affect their phenology have not been reported prior to this study. However, a number of factors influence phenology of species thus varying the time to start and duration of each phenophase among and within plant species. Among a majority of factors, the response to chilling and heat units by plants in order to break bud dormancy is a factor instigating timing and duration of phenophases (Maseyk et al., 2008; Vitasse et al., 2009; Chuine, 2010; Pau et al., 2011; Fu et al., 2012; Fu et al., 2014; Wolkovich and Cleland, 2014); which represents a critical ecological and evolutionary trade-off between survival and growth (Aasa et al., 2004; Ruml and Vulić, 2005; Xia and Wan, 2012). Therefore, variation in the timing of reproductive phases due to differences in species life history will influence the intensity of the reproductive phase (Louw, 2006).

In accordance, the mean time to start of flowering for *C. subternata* was shorter compared to *C. genistoides* (25.9 versus 51.2 days), also for fruiting (46.1 versus 61.5 days) and seed dispersal (96.3 versus 110 days), respectively. However, the duration of flowering (13.2 versus 24.3 days), fruiting (45.6 versus 52.2 days), and seed dispersal (4.3 versus 8.9 days) was shorter in *C. genistoides* compared to *C. subternata*.

If the response to cold and warm temperatures are ascertained to cause variation in the timing and duration of the *Cyclopia* species, the chilling requirement of *C. subternata* to release bud dormancy could be much smaller, thus requiring a longer period of warming in turn lengthening the phenophases' duration. This probably allows enough time for biomass accumulation for fruit and seed set compared to *C. genistoides*. In accord with the study findings, phenology although started early, was longer in *C. subternata* than in *C. genistoides*. As a result, in species and/or genotypes where phenophases are shorter, the return on investment is expected to be faster than in plants where phenophases are delayed (Wolkovich and Cleland, 2014). On-going studies have also indicated that *C. subternata* have a higher flowering, fruit set, and seed production than *C. genistoides* (unpublished data).

Furthermore, factors such as water content, soil type and nutrients are also significant in varying phenology (Ruml and Vulić, 2005; Adair and Burke, 2010; Azad, 2012; Jochner et al., 2013). Soil stored nutrients especially have varying effects (advancing, delaying, or not affecting) on phenology of plant species (Xia and Wan, 2013) as reported in *Betula pendula* Roth (birch) (Jochner et al., 2013). Therefore, a change in nutrient availability is expected to cause a response in plant growth (Mahdavi-Arab et al., 2014). It is difficult to correlate phenology with water content and soil nutrients in this study since the two species were grown without additions of artificial nutrients and the water content was not quantified since plants were irrigated during periods of rainfall scarcity. However, these species may possess conservative mechanisms that allow them to withstand water shortages and scarcity of soil nutrients, a trait mostly associated with species growing in the Mediterranean climate, although this varies for the different species (Sardans and Peñuelas, 2013). Potentially, the fertiliser requirements and species ability to accrue and utilise resources stored in the soil or additions of nutrients of the two species when cultivated may differ, influencing phenology differently, and thus affecting input costs and seed yield when commercially cultivated.

Among the *Cyclopia* species genotypes, phenophases were prolonged in genotypes such as SKB5, SKB3, SKB15, GG31, GK2, GK1, GK4, and GK6; others had clearly defined peaks i.e. GK3, GK7, GK5, GT2, SGD9, SGD7, SGD1, and STB103; others occurred earlier, i.e. GT1, GG9, GG3, GK8, GG53, GG34, SGD6, SKB13, SKB11, SHL2, and STB1 and lastly, delayed in GK2, GT2, GK4, and GK1, STB102, SKB15, and SKB5. Variability between the *Cyclopia* genotypes could be an indication of high inter-annual variability in phenology due to geographical locations (León-Ruiz et al., 2011) which influences the length of the growing season (Rawat, 2012), owing to a rise in spring air temperature (Cleland et al., 2007; Chuine, 2010); which amongst other factors control the timing of phenophases in plants (Xia and Wan, 2012; Jochner et al., 2013; Xia and Wan, 2013; Schröder et al., 2014). Individual plants therefore have timing of phenophase that are attuned to the varying conditions they experience in their range. This assists in reducing competition for pollinators and other resources in order to maintain co-existence in diverse plant communities (Cleland et al., 2007; Pau et al., 2011; Velásquez-Tibatá et al., 2012).

In natural stands, co-existence of different plant species may lead to hybridisation which creates genetic diversity and thus formation of new species or increasing genetic variation within species (Orians, 2000; López-Caamal and Tovar-Sánchez, 2014). However, when hybridisation arises as a result of human disturbances or habitat fragmentations, it will result in a compromise in species' biodiversity causing extinction of closely related species especially when their distribution restricted (Selbo and Snow, 2004; Curtu et al., 2007; López-Caamal and Tovar-Sánchez, 2014). In cases where related species occur at different altitudes over relatively short distances, it may be possible that hybrid zones can be formed between them which serve as pathways for interspecific gene flow. Under such circumstances, analysing hybrid zones assist in understanding of the genetic basis of adaptation to conditions at different altitudes (introgression), and maintenance of species divergence in the face of gene flow (Abbott and Brennan, 2014).

The effect of geographical location on phenology of the *Cyclopia* species was not ascertained since all cuttings from the different provenances were planted within an identical environment (Elsenburg), curtailing environmental variation. Therefore, phenology differences potentially could be due to geographical locations at which the cuttings were initially collected, in accordance with Vitasse et al. (2009) and Azad (2012). The altitude of Elsenburg where the species genotypes were monitored for their phenophases differed from that of the areas where clonal material was initially collected before being rooted and grown at Elsenburg (Table 1). Therefore, cultivation of *Cyclopia* genotypes from the Haarlem, Groendal, and Kanetberg may thus be expected to advance their phenology at the Elsenburg site compared to that from the Tolbos, Koksrivier, Toekomst, and Gouriqua due to altitudinal (temperature) differences between the sites. In accordance, phenophases were advanced in SGD6, SKB13, and SHL2 compared to STB101, GK1, GT2, and GG31. However, variability was also observed for genotypes from the same geographical area such as in STB1 and STB103; GT1 and GT2; which could likely be genetically controlled within species (Castro-Díez and Montserrat-Martí, 1998; Fenner, 1998; Azad, 2012). Other factors apart from genetics may be potentially influencing phenophase variability since in other genotypes such as GG3 and GG9; GK1 and GK2; SKB3 and SKB4, no differences were observed. Therefore, this could likely be as a result of reduced environmental variation when different clones from different origins are grown under the same environment (Azad, 2012).

During the year 2013, observation and recording of phenology data were prolonged compared to 2014. This could be ascribed to the fact that in 2013, the period of cold and winter precipitation was extended which could have lengthened the bud development phase thus lengthening the growing season. The average maximum, minimum temperature and rainfall recorded indicated a slight temperature increase and rainfall diminution in 2014 compared to 2013, which may have contributed to the delay in timing of flowering in 2013 which began during the 35th week compared to the 32nd in 2014 in the case of SGD6. Evidently, seed dispersal of both species pods (*C. subternata* and *C. genistoides*) was delayed in 2013 compared to 2014. Seed dispersal commenced on the 47th week and 49th week in 2013 compared to the 44th week and 45th week in 2014, respectively. The acceleration of phenophases by approximately three weeks in 2014 compared to 2013, echoes Fenner (1998) who stated that a triggering of the phenophases response is effected by the ability of the plant to detect environmental cues.

Cultivation of *Cyclopia* species in areas or during years associated with warmer accompanied by low rainfall conditions may thus be expected to accelerate and squatter the length of their reproductive development. In contrast, in areas or years when conditions are colder and rainfall is higher, the start dates of phenophases may be extended. Consequently, the environment prevailing weather conditions where *Cyclopia* species are cultivated may thus play a significant role in altering phenology thus seed production yield, time of harvest, and harvest strategies since species genotype will vary in their maturing of seed. *Cyclopia* differences in phenological pattern due to climatic differences will thus have an implication on their natural fecundity, since plants seed set is regulated by the timing of switches between vegetative and reproductive phases (Cleland et al., 2007). Early and late flowering individuals may thus be prone to seed predation than mid-season individuals due to saturation effect at peak of abundance as suggested by Fenner (1998). Therefore, the influence of phenology on the fecundity as a result of climatic differences, are expected to result in unpredictable selective pressures favouring early, average, or late individuals in different years, hence variations in their pollinator or seed predator abundance.

The current scale used for observation could have also caused variations in the length of each phenophase between and within species, since no observations were recorded during adverse weather conditions (preventing field access). Therefore, the observational intervals (weekly) could be modified for future studies to two or three observations per

week or daily in order to reflect variations in the phenophases. Furthermore, coding systems such as the Biologishe Bundesanstalt, Bundessortenamt and CHemical Industry (BBCH) (Saska and Kuzovkina, 2010), physiologically based with statistical approach mathematical models (Ruml and Vulić, 2005) can be used to accurately predict phenophases in *Cyclopia* plants.

Plants monitored for phenology studies were also of different sizes and age which could have contributed to differences in timing of phenophases (Jochner et al., 2013; Schröder et al., 2014). Noticeable, the seed dispersal duration of STB101, GG9, GG34, GT2, and GK1 was 0.0 days. This could have been due to lack of sample plants and plant size or a combination of both to allow for variation. The majority of these genotypes were characterised by having a small and low plant size and height, with very few short inflorescences. Having smaller and less plants with few and short inflorescences could have accelerated harvesting of pods to be completed between observational days, hence the zero value. In contrast, genotypes with enough sampling and larger plants, with numerous inflorescences extended harvesting causing variation probably due to varying ripening stages of pods per inflorescence per plant. Therefore, use of individual plants with similar growth form, size, and age, and improved management practices may be expected to enhance outcomes of this study. However, the challenge of achieving the latter remains high not only due to insufficient study sites and plant material, but as a direct result of huge variations in germination currently observed between genotypes (unpublished data), thereby limiting availability of large numbers of rooted plant material of similar age. Furthermore, natural disasters such as fires occur almost annually, destroying or partially destroying *Cyclopia* plantations (as was the case for this study).

5. Conclusions

Preliminary findings indicated differences in phenology between and within species (*C. subternata* and *C. genistiodes*) and that time to start of phenophases is inversely proportional to phenology duration. This is the first practical study that confirms that flowering in *C. subternata* and *C. genistoides* occurs between September and October although differences within species are inevitable. Studies are needed to determine the exact start of budding in order to refine the peak period and duration of budding since in this study, budding was already initiated by the first field observation day. Certain phenophases such as bud development and fruiting (pod development) were observed to have longer developmental phases while in flowering and seed dispersal phenophases were shortened. However, prevailing weather conditions could play a significant role in altering seed dispersal since it appears that very hot and dry conditions accelerate pod and seed maturation. These findings serve as a platform for investigating factors affecting the reproductive phases, morphological and physiological studies in *Cyclopia* species, and assist farmers and researches especially breeders for timing of crop requirements and management practices.

The study provides a future opportunity to study the potential relation of phenology and root length, fruit size, fecundity, geographical location (altitude and latitude), climatic conditions, nutrients, irrigation, photoperiod, chilling units, plant stand characteristics (population size), plant size and age, pollination/pollinator mechanisms, and photosynthetic activity among others which affect timing and/or switches in plant species phenology. Future observation over a number of years and across sites on some of these factors could yield better results and understanding in the phenological dynamics of this South African herbal tea genus, and use of more reliable phenological data and models developed for larger geographical areas rather than for a single location.

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