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RESEARCH

Emergence Pattern of *Argemone mexicana*, *Brassica tournefortii*, and *Rapistrum rugosum* in Eastern Australia

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Abstract

A study assessed the potential for using cumulative growing degree days (CGDD) to predict the weed emergence periodicity of three weed species: *Argemone mexicana*, *Brassica tournefortii*, and *Rapistrum rugosum*. Weed emergence was monitored regularly by placing 200 fresh seeds of each weed species on the soil surface. Weed emergence data was fit using a three-parameter sigmoidal Gompertz model. The CGDD required for 50% emergence of *A. mexicana* ranged from 3380 to 5302, depending upon the seasonal variation in temperature and rainfall. The majority of emergence appeared from March to June. The seeds of *A. mexicana* exhibited dormancy, as the majority of seeds germinated in the second season. The CGDD required for 50% emergence of *B. tournefortii* ranged from 824 to 2311, depending upon the seasonal variation in temperature and intensity of rainfall. Most cohorts of *B. tournefortii* appeared in the first season from February to June, indicating little dormancy in seeds. The CGDD required for 50% emergence of *R. rugosum* ranged from 2242 to 2699, depending upon weather parameters (temperature and rainfall). The main cohorts of *R. rugosum* appeared from February to June, and 60% of seeds germinated in the first season, while 40% germinated in the second season, indicating dormancy in seeds. The coefficients of determination for the model verification on the emergence pattern of three weeds were >85%, suggesting that CGDD are good predictors for the emergence of these weeds. These results suggest that forecasting the emergence of three weed species on the basis of CGDD and rainfall patterns will help growers to make better weed management decisions.

Keywords Cumulative growing degree days · Weed competition · Weed emergence models · Weed management decisions

Introduction

Knowledge of weed emergence time is very important for developing their control strategies, particularly for weeds that are established through seeds (Mohler 2001; Ryan et al. 2010). The timing of weed emergence is correlated with the biological attributes of the weed and the interaction of these attributes with environmental and management conditions (Cordeau et al. 2017). Therefore, improved knowledge of weed emergence periodicity may strengthen weed management programs (Norsworthy et al. 2012; Reinhardt-Piskackova et al. 2020). The timing of weed control, the sowing time of the crop, and seedbank depletion strategies (e.g., tillage) can be adjusted for the disfavour of weeds by having a thorough understanding of the weed emergence pattern (Sousa-Ortega et al. 2020; Batlla et al. 2020; Nordell and Nordell 2009).

The emergence of weeds varies with species, seed dormancy, pre-emergence growth habits, and prevailing environmental conditions (Batlla et al. 2020). Weeds with a wider emergence period are more difficult to control than weeds with a narrower emergence period. Modelling efforts are utilised to predict cumulative emergence and peak emergence time in relation to environmental conditions or growing degree days (GDD) using Weibull or Gompertz functions (Forcella et al. 1997; Royo-Esnal et al., 2020; Chauhan and Johnson, 2010). The peak emergence time of

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weeds could be helpful in deciding on timely weed management (Kumar et al. 2018).

In the northern grain region of eastern Australia, *Argemone mexicana* is considered one of the top 20 costly weeds (Llewellyn et al. 2016). This weed is a poor competitor in narrow-row crops, such as wheat (*Triticum aestivum* L.); however, it could cause substantial yield losses in chickpeas (*Cicer arietinum* L.) (Manalil and Chauhan 2019; Mahajan and Chauhan 2023). Seeds of *A. mexicana* have a resemblance to mustard seeds (*Brassica nigra),* and their mixing/adulteration in edible mustard oil could cause epidemic dropsy if consumed by humans in cooking (Verma et al. 2001). The yellow sap of the plant is poisonous to cattle due to the presence of berberine and potassium nitrate (Alam and Khan 2020; Vandebroek et al. 2020). In chickpea crops and under fallow conditions, *A. mexicana* could produce enough seeds to build up the seedbank in the soil due to its shattering behaviour (GRDC 2017). The fresh seeds of *A. mexicana* are dormant (Karlsson et al. 2003). The longevity of *A. mexicana* seeds is lower on the soil surface compared with buried seeds (Manalil and Chauhan 2021). The contamination of *A. mexicana* seeds in crops and fodder may reduce marketing quality. Moreover, the prickly nature of this weed may cause injury to humans and animals when in contact (GRDC 2017). Information on the emergence pattern of *A. mexicana* is limited in Australia, and an improved understanding of emergence periodicity may help in timely weed management.

Brassica tournefortii is a winter weed that is very prolific in seed production (Alemseged et al. 2001). The biological attributes, such as the ability to grow under a wide range of temperatures (15/5 to 35/15°C, day/night) and drought conditions, make this weed more invasive in Australia under different agro-ecological conditions (Mahajan et al. 2020; Singh et al. 2021). Under fallow conditions, this weed can produce up to 10,000 seeds/plant. The high seed-shattering tendency and ability to persist for a long time (>2 years) in shallow soil layers could increase its infestation in the no-till cropping systems of Australia (Mahajan et al. 2020). Under Australian conditions, a 50% yield reduction in chickpeas could occur at a weed density of 10 plants m^{-2} (Mahajan and Chauhan 2023). However, this weed is a poor competitor in wheat crops, and its high infestation can cause only a 5–10% reduction in wheat yield (Gill et al. 2022; Chauhan et al. 2006). The evolved resistance of this weed to Group 2 herbicides in Australia necessitates its timely weed management (Alemseged et al. 2001). The filling of research gaps regarding the emergence periodicity of this weed may strengthen integrated weed management programs.

Rapistrum rugosum is widespread in Australia, and recently, infestations of this weed have become more prevalent in eastern Australia (Manalil et al. 2018). This weed in competition with wheat, could produce 32,000 seeds m^{-2} (Manalil and Chauhan 2019). Under fallow conditions, one single plant has the potential to produce 13,000 seeds (Mobli et al. 2020). The biological attributes, such as the ability to emerge under a wider range of temperatures (15/5 to 35/25 °C; day/night temperatures), high seed production potential, fast growth (took 57 days to flower), and long persistence (>3.5 years) of seeds in a shallow layer, are the reasons for its wider adaptation in Australia (Manalil et al. 2018; Mobli et al. 2020; Singh et al. 2021). In Australia, *R. rugosum* has evolved resistance to Group 2 herbicides and, therefore, requires strategic weed management programs based on an understanding of its emergence pattern (Hatami et al. 2016).

Knowledge gaps exist in relation to the emergence patterns of these three weeds, viz., *A. mexicana*, *B. tournefortii*, and *R. rugosum*, in eastern Australia. Information on weed emergence timing is important for developing suitable strategies for weed control and can strengthen decision-support systems for weed management (Chauhan et al. 2012; Mahajan and Chauhan 2021). It was hypothesised that populations of these three weeds collected from different environmental conditions might have adaptative traits for varied emergence patterns when tested under the same environmental conditions. Therefore, the objective of this study was to determine the emergence pattern of various populations of three important winter season weeds (*A. mexicana*, *B. tournefortii*, and *R. rugosum*) collected from different cropping regions of Australia.

Materials and Methods

The study comprised nine populations of *A. mexicana*, eight populations of *B. tournefortii*, and 10 populations of *R. rugosum* at the Gatton Research Farms (27.5514° S/152.3428° E) of the University of Queensland, Australia. Populations of different weeds selected for the study were collected from paddocks in the eastern region of Australia in October 2018. After collection, seeds were air-dried for 7 d in a screenhouse and then used in the study. Seeds were used immediately to coincide with the natural seed-shattering time of these weeds. The first and second experimental studies were commenced on December 2, 2018 and December 10, 2019, respectively.

The study was conducted by spreading 200 seeds in rings (made up of plastic) that were placed in the field (27.5514° S/152.3428° E). The diameter and height of the ring were 30 cm and 5 cm, respectively. Seeds in the rings were spread on the soil surface. Seedling emergence was counted regularly at 7 d intervals. Emerged seedlings were killed using spot herbicide (glyphosate at 740 g a.e. ha^{-1}) applications each time seedlings were counted. Seedling

emergence data were recorded for more than two years. The seeds for the second-year study were stored in a refrigerator at 4 °C to maintain the dormancy level of the seeds (Kumar et al. 2018), which was similar to the first year.

Weather Parameters

During the study, weather observations, viz., minimum and maximum air temperatures and rainfall, were recorded from the Bureau of Meteorology (BOM), Australia (http://www.bom.gov.au/climate/dwo/).

Statistical Analyses

Populations of three selected weeds showed a similar trend for emergence behaviour; therefore, all the tested populations for each species were pooled to calculate the emergence percentage of the maximum. Emergence pattern graphs were plotted using SigmaPlot 14.0 (Systat Software, San Jose, CA, USA). Daily emergence counts during the study were converted into cumulative percentages of total seeds, and the means of different populations were compared with standard errors.

Cumulative emergence was described as a function of GDD using Sigma Plot 14.0, and data were presented separately for each year as the year's effect was significant. The data were subjected to a three-parameter sigmoidal Gompertz model:

$$y = a^{*}\exp^{[-\exp(-x-x0)/b]} \quad (1)$$

where, y is the total cumulative emergence (%) at time x, b indicates the slope, a is the maximum emergence (%), and $x0$ is the estimated time (GDD) for 50% emergence (%). GDD was calculated using the formula:

$$GDD = ((T_{max} + T_{min})/2 - T_b) \quad (2)$$

where T_{max} and T_{min} are the maximum and minimum air temperatures, and T_b is the base temperature (5 °C) for winter species (Vigil et al. 1997).

Results and discussion

Argemone mexicana

Emergence data in each experimental year were recorded for more than 24 months until emergence ceased. In the first experiment, multiple cohorts (eight cohorts) of *A. mexicana* appeared from March 2019 to June 2020 (Fig. 1; Tables 1 and 2). The emergence was 0.3% (of the maximum) on March 22, 2019 [2374 cumulative growing degree days (CGDD)], which increased to 5% on June 28, 2019 (2992 CGDD). This emergence in the second season further increased to 71 and 91% (of the maximum) on January 24, 2020 (7146 CGDD) and March 27, 2020 (8410 CGDD), respectively. The cumulative emergence of *A. mexicana* in the first-year experiment reached its maximum on June 19, 2020 (9577 CGDD; about 535 days after seed spread).

In the second experiment, five cohorts of *A. mexicana* appeared from January 2020 to April 2021. The emergence was 3% on January 21, 2020 (906 CGDD), which increased to 51% on March 24, 2020 (2292 CGDD), and reached its maximum on April 2, 2021 (8157 CGDD). The regression analysis predicted that the CGDD required for 50% emergence of *A. mexicana* was 5302 and 3380 in the first and second-year experiments, respectively (Fig. 1 and Table 2).

In the first experiment, rain events of > 10 mm did not appear in January and February 2019 (the first season), while in the second experiment (the first season), there were three and five events of > 10 mm rainfall in January and February 2020, respectively (Table 3). High rainfall at the start of the second year experiment could be the reason for the lower CGDD for the 50% emergence of *A. mexicana* in the second experiment compared with the first experiment. These observations suggest that high rainfall (> 10 mm) in January and February (the start of the summer season) enhanced the emergence of *A. mexicana* and decreased the CGDD for emergence. If rainfall is low (< 10 mm: not ef-

Table 1 Fitness of weed emergence data sets to the non-linear function Gompertz for three weed species (averaged over populations)

Weed species	Experiment	$a \pm$ SE	$b \pm$ SE	$x0 \pm$ SE	R^2
Argemone mexicana	First	104 ± 8	2041 ± 256	5302 ± 286	0.99
	Second	105 ± 14	2332 ± 994	3380 ± 896	0.99
Brassica tournefortii	First	102 ± 5	158 ± 58	2311 ± 44	0.98
	Second	98 ± 2	663 ± 94	824 ± 110	0.99
Rapistrum rugosum	First	99 ± 8	1730 ± 617	2699 ± 208	0.91
	Second	96 ± 20	2630 ± 1521	2242 ± 830	0.87

a = upper asymptote (theoretical maximum percent emergence), b = slope parameter (emergence rate), x_0 = cumulative growing degree days for 50% emergence, R^2: coefficients of determination, *SE* Standard error

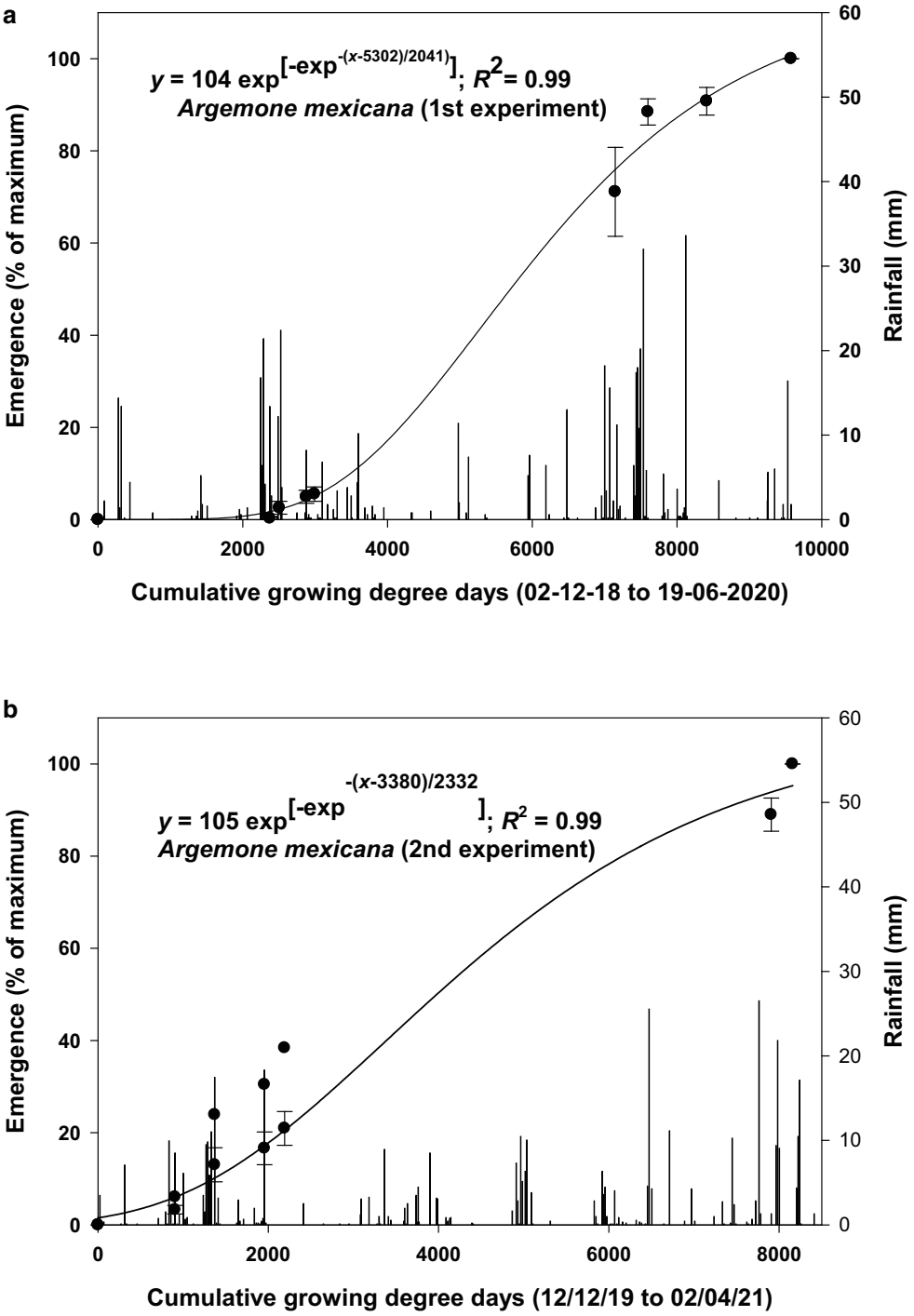


Fig. 1 The emergence pattern of *Argemone mexicana* (means of nine populations) in relation to cumulative growing degree days **a** the first experiment starting from December 2018 and ending in June 2020; **b** the second experiment starting from December 2019 and ending in April 2021. Vertical bars represent daily rainfall. Error bars indicate standard error (±). The line represents a three-parameter sigmoidal Gompertz model fit to the data and *y* is the total cumulative emergence (%) at time *x*

fective rainfall) in the months of January and February, most seeds of *A. mexicana* remain dormant and germinate at a time when favourable environmental and soil moisture conditions are available. It has been suggested that 10 mm of rainfall (effective rainfall) could allow germination and emergence of winter plants such as wheat in most soil types in Australia (Clarke et al. 2019). Therefore, we have assumed that the three winter weeds require sufficient moisture (effective rainfall) in the surface layer of soil for germination.

In Australia, farmers keep their fields fallow after harvesting summer crops, such as sorghum [*Sorghum bicolor* (L.) Moench], maize (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), etc. *Argemone mexicana* has a tendency for peak emergence in February and March if sufficient rainfall is available; therefore, this weed could emerge and grow luxuriantly in the winter seasons and reinfest and en-

rich the seedbank in the soil by producing more seeds. The infestation of *A. mexicana* in fallows has been observed in many parts of eastern Australia (GRDC 2017). One plant of *A. mexicana* could produce up to 30,000 seeds (https://portal.wiktrop.org/species/show/29); therefore, this weed could invade the fallow systems of Australia if it is not controlled. Further, *A. mexicana* is poisonous to humans and livestock (CottonInfo 2014), and its infestation in pasture land and *Brassica*/canola crops may injure humans and livestock (CottonInfo 2014).

The seeds of *A. mexicana* have innate dormancy, and the mechanism for its dormancy is not well understood (Manalil and Chauhan 2021). Dormant seeds of *A. mexicana* in the field are a concern and may increase weed seed persistence. However, this weed has poor competitive ability with closely spaced crops, such as wheat, barley (Hordeum vulgare L.), etc., and is unable to produce seeds in these crops (Manalil and Chauhan 2019). Therefore, an infestation of this weed in Australian fields could be reduced by exploiting crop competition using narrow-row crops and a high seeding rate. As this weed has a higher tendency to emerge before the start of winter seasons (evident from the data), pre-sowing tillage or the use of nonselective herbicides before winter crop sowing could eliminate this weed from the paddocks.

Brassica tournefortii

In both experimental years, multiple cohorts of *B. tournefortii* appeared. In the first experiment, emergence was 1% (of the maximum) on February 21, 2019 (1761 CGDD), which increased to 66 and became maximum on March 29, 2019 (2506 CGDD) and April 26, 2019 (2960 CGDD), respectively (Fig. 2; Tables 2 and 5). In the first experiment, cohorts of *B. tournefortii* did not appear in the second season, suggesting that seeds had low dormancy on the soil surface layer.

Table 2 Cohorts detail of *Argemone mexicana* with time (averaged over nine populations)

Cohorts number	Calendar day (DD-MM-YY)	Cumulative growing degree days	Cumulative emergence (% of maximum)
First Experiment			
1	22-03-2019	2374	0.29
2	29-03-2019	2506	2.57
3	21-06-2019	2878	4.95
4	28-06-2019	2992	5.54
5	24-01-2020	7146	71.1
6	14-02-2020	7598	88.4
7	27-03-2020	8410	90.8
8	19-06-2020	9577	100
Second Experiment			
1	21-01-2020	906	3.29
2	11-02-2020	1371	43.0
3	10-03-2020	1955	43.6
4	24-03-2020	2192	50.9
5	02-04-2021	8157	100

Table 3 Calendar days with rainfall > 10 mm from 2018–19 to 2020–21 (the first experiment was started on December 2, 2018, and the second experiment was started on December 10, 2019)

Year			
2018	2019	2020	2021
15-Dec	16-Mar	18-Jan	7-Jan
17-Dec	18-Mar	21-Jan	19-Jan
	22-Mar	25-Jan	24-Feb
	28-Mar	6-Feb	11-Mar
	30-Mar	7-Feb	22-Mar
	17-Jun	8-Feb	23-Mar
	12-Oct	9-Feb	24-Mar
	25-Dec	11-Feb	6-Apr
		10-Mar	7-Apr
		15-Jun	
		8-Aug	
		22-Oct	
		25-Oct	
		28-Oct	
		20-Oct	

In the second experiment, the first cohort of *B. tournefortii* appeared on February 15, 2020 (1455 CGDD) with 71% emergence (Table 4). This emergence increased to 97% on June 14, 2020 (3352 CGDD). One cohort of *B. tournefortii* in the second experiment appeared on April 2, 2021 (8157 CGDD). The regression analysis predicted that the CGDD requirements for 50% emergence of *B. tournefortii* was 2311 and 824 in the first and second experiments, respectively.

These results suggest that most seeds of *B. tournefortii* germinate in the first season if sufficient rainfall is available. The rainfall at the experimental site from January to March 2019 was lower compared with 2020 (Table 3). Therefore, relatively higher rainfall from January to March 2020 could be the reason for less CGDD for the 50% emergence of *B. tournefortii* in 2020 compared with 2019. About 98% of seeds of *B. tournefortii* germinated in the first season, suggesting that seeds of *B. tournefortii* had lower dormancy compared with *A. mexicana*. Contrary to this, in our previous laboratory study, it was found that seeds of *B. tournefortii* had dormancy and germination increased in a dark environment or with NaOCl treatment (Mahajan et al. 2018). It is quite possible that under field conditions with the onset of sufficient rainfall, chemicals present in the soil are dissolved, which may result in the breaking of dormant seeds.

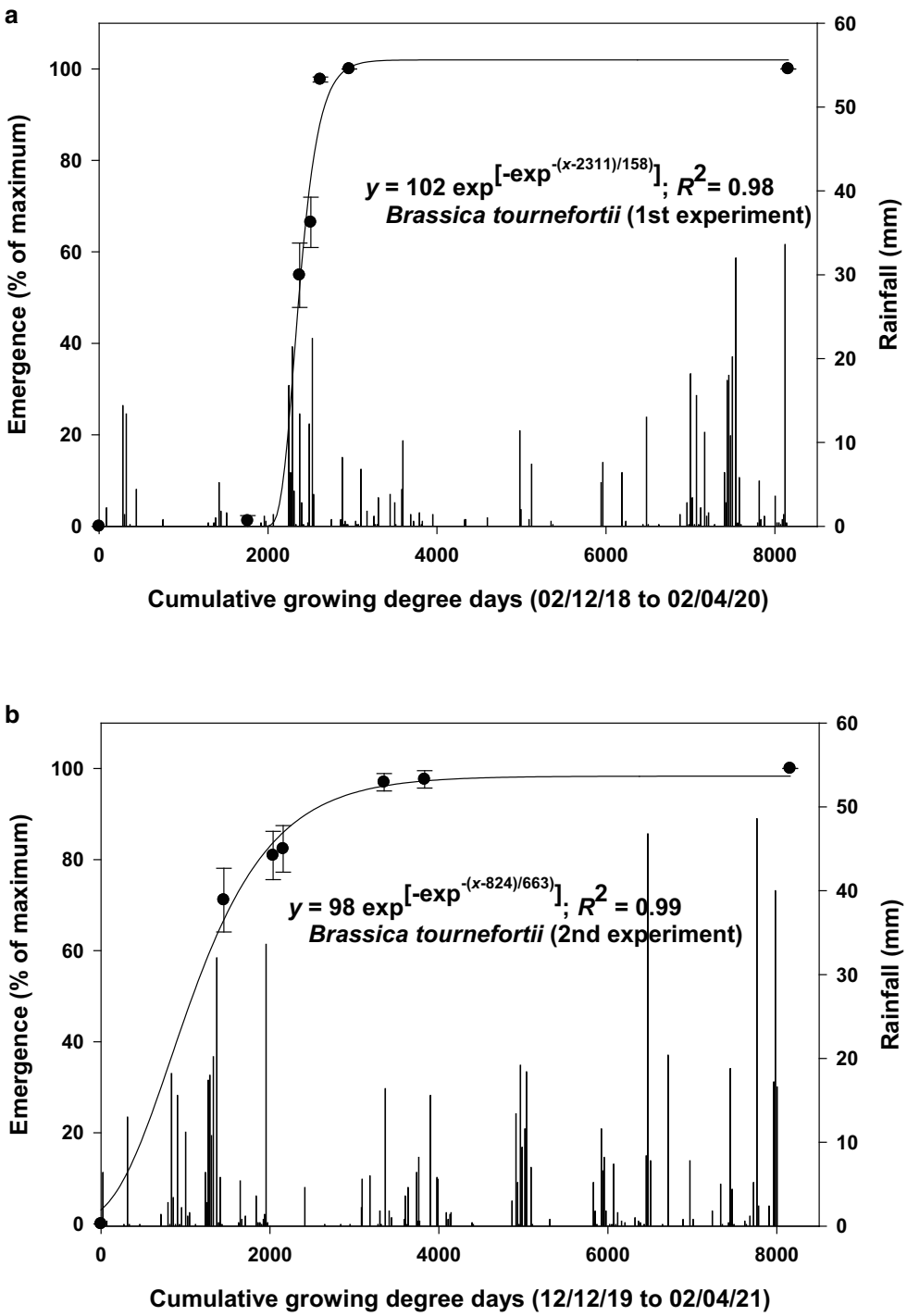


Fig. 2 The emergence pattern of *Brassica tournefortii* (means of eight populations) in relation to cumulative growing degree days **a** the first experiment starting from December 2018 and ending in April 2020; **b** the second experiment starting from December 2019 and ending in April 2021. Vertical bars represent daily rainfall. Error bars indicate standard error (±). The line represents a three-parameter sigmoidal Gompertz model fit to the data and *y* is the total cumulative emergence (%) at time *x*

The little dormancy of *B. tournefortii* on the soil surface layer suggests that restricting seed production in the no-till field could eliminate this weed in a shorter time. However, the ability of this weed to produce a high number of seeds could increase its infestation in fallows (Mahajan et al. 2020). It has been observed that one plant of *B. tournefortii* could produce 5500 seeds, and the high shattering tendency of this weed could reinfest the area (Mahajan et al. 2020). *Brassica tourneforii* could grow under a wide range of temperatures, suggesting that in slow-growing winter crops, such as chickpeas, its infestation could increase due to less competition offered by the crop (Singh et al. 2021). Herbicide options for controlling broad-leaf weeds in crops, such as chickpeas, are limited (Shahbazi et al. 2019). Therefore, its infestation in such crops may build up the seedbank in the soil if not timely controlled. The ability of this weed to produce enough seeds in a drought environment could increase its invasion in fallows (Mahajan et al. 2020). The

Table 4 Cohorts detail of *Brassica tournefortii* with time (averaged over eight populations)

Cohorts number	Calendar day	Cumulative growing degree days	Cumulative emergence (% of maximum)
First Experiment			
1	21-12-2019	1761	1.16
2	22-03-2019	2374	54.9
3	29-03-2019	2506	66.4
4	05-04-2019	2619	97.7
5	26-04-2019	2960	100
Second Experiment			
1	15-02-2020	1455	71.1
2	15-03-2020	2038	80.9
3	22-03-2020	2157	82.4
4	14-06-2020	3352	97.0
5	02-08-2020	3831	97.6
6	02-04-2021	8157	100

poor competitive ability of this weed in narrow row crops, such as wheat and barley, could reduce seed production for reinfestation in that area. It is essential to control this weed in winter fallows with the help of herbicides to reduce seedbank.

Rapistrum rugosum

In the first experiment, 14 cohorts of *R. rugosum* appeared from March 2019 to March 2020. Similarly, in the second experiment, 12 cohorts of *R. rugosum* appeared from February 2020 to April 2021 (Table 5).

In the first experiment, the first cohort of *R. rugosum* appeared on March 22, 2019 (2374 CGDD) with 16% (of the maximum) emergence (Fig. 3; Table 2). This emergence increased to 45, 60, and 62% on April 5 (2619 CGDD), June 28 (3700 CGDD), and July 12 (3854 CGDD) 2019, respectively. In the second season, this emergence increased to 97% on 14 February 2020 (7236 CGDD) and reached its maximum on March 27, 2020 (8057 CGDD).

In the second experiment, the first cohort of *R. rugosum* appeared on February 7, 2020 (1288 CGDD) with 1% emergence (Fig. 3). This emergence increased to 41, 50, and 55% on April 5 (2005 CGDD), August 7 (3885 CGDD), and November 13 (5291 CGDD) 2019, respectively. In the second season, this emergence increased to 60% on March 19, 2021 (7907 CGDD) and became maximum on April 2, 2021 (8157 CGDD). The regression analysis predicted that the CGDD required for 50% emergence of *R. rugosum* was 2699 and 2242 in the first and second experiments, respectively (Fig. 3).

In both experiments, almost 40% of the seeds of *R. rugosum* germinated in the second season, suggesting that this weed also has a strong dormancy. These results also showed

Table 5 Cohorts detail of *Rapistrum rugosum* with time (averaged over ten populations)

Cohorts number	Calendar day	Cumulative growing degree days	Cumulative emergence (% of maximum)
First Experiment			
1	22-03-2019	2374	16.4
2	29-03-2019	2506	31.0
3	05-04-2019	2619	45.1
4	26-04-2019	2960	46.3
5	24-05-2019	3344	46.6
6	14-06-2019	3560	46.9
7	21-06-2019	3634	59.1
8	28-06-2019	3700	60.1
9	05-07-2019	3780	61.9
10	12-07-2019	3854	62.0
11	24-01-2020	6805	63.7
12	14-02-2020	7236	97.5
13	13-03-2020	7805	99.4
14	27-03-2020	8057	100
Second Experiment			
1	07-02-2020	1288	1.14
2	14-02-2020	1432	35.0
3	13-03-2020	2005	40.8
4	20-03-2020	2116	41.8
5	17-07-2020	3670	48.0
6	31-07-2020	3812	48.7
7	07-08-2020	3885	50.0
8	18-09-2020	4375	51.0
9	13-11-2020	5291	54.8
10	22-01-2021	6768	57.0
11	19-03-2021	7907	60.7
12	02-04-2021	8157	100

that the temperature conditions of February and March were ideal for the emergence of this weed, provided there was a sufficient amount of rainfall available.

Rapistrum rugosum produced multiple cohorts throughout the year due to its adaptability to a wide range of temperatures (15/5 C to 30/20 °C) for emergence (Manalil et al. 2018). Previous studies have reported that this weed is highly competitive in winter crops, such as wheat and chickpea, and prolific in seed production (Mobli et al. 2020; Mahajan and Chauhan 2023). The high infestation of this weed could create problems in harvesting winter crops such as wheat, barley, chickpea, etc. However, the high seed retention ability of this weed provides an opportunity for harvest weed seed control (Manalil and Chauhan 2021). Early (April-May) cohorts of *R. rugosum* produced more seeds compared with late cohorts (June-July) (Mobli et al. 2020). Efforts should be made to control early cohorts of this weed in slow-growing winter crops, such as chickpeas. Late cohorts can also produce sufficient seeds in fallows;

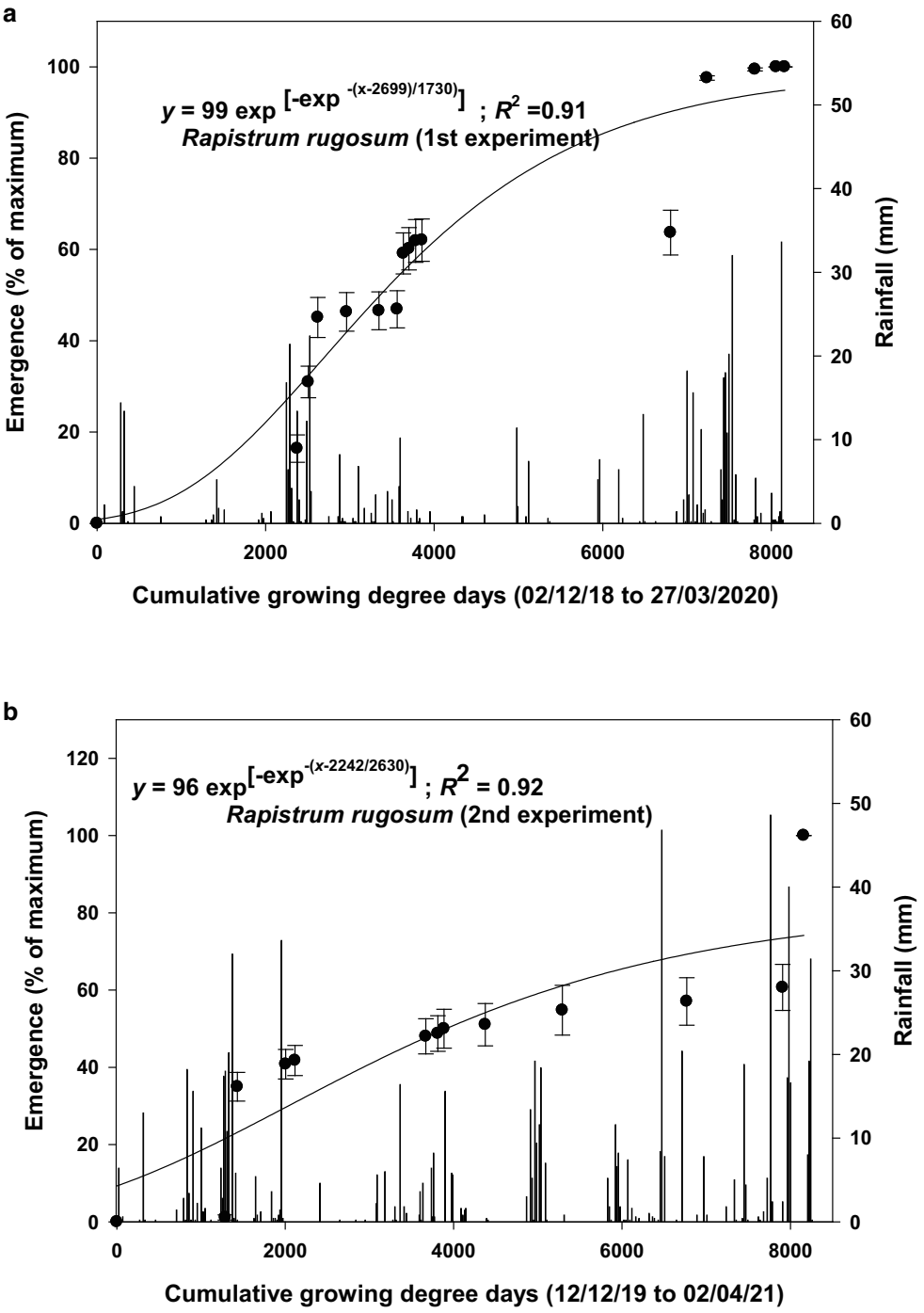


Fig. 3 The emergence pattern of *Rapistrum rugosum* (means of ten populations) in relation to cumulative growing degree days **a** the first experiment starting from December 2018 and ending in March 2020; **b** the second experiment starting from December 2019 and ending in April 2021. Vertical bars represent daily rainfall. Error bars indicate standard error (±). The line represents a three-parameter sigmoidal Gompertz model fit to the data and *y* is the total cumulative emergence (%) at time *x*

therefore, allowing surviving plants of *R. rugosum* in fallows may increase its seedbank in the soil. Late cohorts of *R. rugosum* in winter crops could escape from the early application of post-emergence herbicides, In such situations, integrated control of this weed using agronomic practices, such as narrow row spacing, adjusting planting time, and exploring weed competitive cultivars may reduce the seed production potential of this weed.

In conclusion, knowledge gained from the emergence patterns of *A. mexicana*, *B. tournefortii*, and *R. rugosum* may help in decision-making processes for timely weed control, enhance crop competition, expedite weed seedbank depletion, and strengthen sustainable weed management programs. Weed management decisions can be modified for improved weed control by having a thorough understanding of the season variation and weed emergence patterns of these weeds.

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Author Contribution GM ran the experiment and recorded the data. BSC and GM designed the study. GM wrote the initial draft; BSC edited the manuscript; All authors read and approved the paper.

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Data Availability All relevant data are within the paper and its Supporting Information files.

Conflict of interest G. Mahajan and B. Singh Chauhan declare that they have no competing interests.

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