Tikrit Journal for Agricultural Sciences
ISSN:1813-1646 (Print); 2664-0597 (Online)
Journal Homepage: http://www.tjas.org
E-mail: tjas@tu.edu.iq

TJAS
Tikrit Journal for Agricultural Sciences

DOI: https://doi.org/10.25130/tjas.25.3.8

Thermal requirements, physiological growth, and Grain sterility of some rice (*Oryza sativa* L.) Genotypes grown in different sowing dates

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KEY WORDS:
High temperature, GDD, planting date, infertile rice grain, pot experiment

Received: 03/05/2025
Revision: 15/07/2025
Proofreading: 26/08/2025
Accepted: 08/09/2025
Available online: 30/09/2025

ABSTRACT

The growth and development of rice are significantly impacted by high temperatures, which also increases the sterility percentage. The consequences of extreme heat can be mitigated by selecting appropriate sowing dates for rice genotypes, particularly during flowering. In a pot experiment conducted from April to November 2024, three genotypes of japonica rice and one indica genotype were cultivated using three sowing dates: April 21, May 11, and June 11. Phenology and sterility percentage were ascertained in addition to the accumulation of Growing Degree Days, calculated for every stage from seedling to physiological maturity (PM). The effect of the three different sowing dates and the response of rice genotypes were found to differ significantly. The longest growing period (143.500 days) was for the first date with a maximum amount of GDD (3262.400) needed to reach PM, whereas the third sowing date had the shortest period (114.417 days) and the lowest GDD (2595.338). High temperatures caused differences in sterility among rice genotypes, depending on the environmental conditions provided by three sowing dates; the highest and lowest sterility percentages of V1, V2, and V3 were obtained in SD1 and SD3. The Banikhellan genotype had a far higher grain production (56.001g) than the others, whilst the Indica type produced the least (29.619g). As a result, the Indica genotype Sadry had 40% sterility, whereas the Japonica rice genotypes Banikhellan, Akre1, and Akre2 displayed more tolerance, so any rice genotype's appropriate sowing date greatly depends on the timing of the flowering and pollination.

المتطلبات الحرارية والنمو الفسيولوجي ونسبة عدم الخصب لبعض التراكيب الوراثية للرز النامية في مواعيد زراعة مختلفة

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الخلاصة:
يتأثر نمو وتطور الرز بشكل كبير بدرجات الحرارة المرتفعة، والتي تزيد أيضًا من نسبة عدم الخصب%. ويمكن التخفيف من عواقب الحرارة الشديدة من خلال مواعيد الزراعة المناسبة لمحصول الرز في الأوقات المناسبة لقدرات التراكيب الوراثية، وخاصة في مرحلة الإزهار. أجريت تجربة سنادين من نيسان إلى تشرين الثاني لعام 2024، وتم زراعة ثلاثة تراكيب وراثية من الرز الياباني و تركيب وراثي واحد من رز الهندي باستخدام ثلاثة مواعيد زراعة مميزة: 21 نيسان و11 مايس و11 حوزيران. تمت دراسة صفات النمو ونسبة عدم الخصب بالإضافة إلى تراكم وحدات حرارة النمو اليومية GDD، والتي تم حسابها لكل مرحلة من مراحل النمو من طور البادرات إلى النضج PM. وجد اختلافات معنوية في تأثير مواعيد الزراعة الثلاثة المختلفة واستجابة التراكيب الوراثية. كانت أطول فترة نمو (143.500) يوم للموعد الاول مع اعلى كمية من وحدات حرارة النمو اليومية اللازمة للوصول إلى النضج الفسلجي (3262.40 GDD، بينما احتاج موعد الزراعة الثالث أقصر فترة (114.417) يومًا وأقل كمية من (2595.338 GDD. تسببت درجات الحرارة المرتفعة في ايجاد اختلافات في نسبة عدم الخصب بين التراكيب الوراثية للرز، اعتمادًا على الظروف البيئية التي توفرها مواعيد الزراعة المختلفة، تم الحصول على أعلى وأقل نسبة عدم الخصب لـلتراكيب الوراثيةV1,V2,V3 في الموعدين الاول و الثاني SD1 SD3. كان هناك تفوق معنوي للتركيب الوراثي باني خيلان في إنتاج الحبوب (56.001 جم) مقارنة بالتراكيب الوراثية الأخرى، في حين أنتج التركيب الوراثي الإنديكا أقل كمية من الحبوب (29.619 جم). و كان لدى التركيب الوراثي الهندي صدري40 ٪نسبة عقم، في حين أظهرت التراكيب الوراثية للرز الياباني بانيخيلان, عقرة1, عقرة 2 المزيد من التحمل, لذا فإن موعد الزراعة المناسب لأي تركيب وراثي للأرز يعتمد بشكل كبير على توقيت مرحلة الإزهار والتلقيح. .
الكلمات الدالة: ارتفاع درجة الحرارة، موعد الزراعة، درجات النمو اليومية, حبوب الرز غير المخصبة، تجربة سنادين

INTRODUCTION

Rice (*Oryza sativa* L.) will continue to be the most important staple food in the world in the ensuing decades. Even while rice production has advanced significantly, the population of countries that consume it is still growing, which raises the demand for rice. The growth and production of rice crops, as well as the increase in the farmed area, are mostly determined by environmental conditions (Manoj Kandel *et al.,* 2018). One of the numerous agronomic factors influencing rice productivity is the planting date; given climate change, changing the sowing date becomes essential. According to (El-Ramady *et al.,* 2013), mitigation and adaptation could alter the majority of climate change's consequences on sustainable agriculture. The adoption of heat-tolerant rice cultivars seems an effective countermeasure to global warming(Nakagawa *et al.,* 2005). Such cultivars could help maintain rice output in the face of the global warming phenomenon by increasing the probability of production in extremely hot areas and seasons. In addition to previous improvements, the linguistic aspect was addressed as much as possible. In addition to previous improvements, the linguistic aspect was addressed as much as possible. Temperature is considered a significant climatic factor influencing plant growth and development of rice crops from planting to maturity. The accumulated heat units assess the relationship between growth and prevailing temperatures of the growing conditions. Growing degree days operate on the principle that the time required to reach a phenological stage is directly proportional to the temperature. Growing Degree Days, or Crop Heat Units, are measured in units. They are defined as the total amount of heat needed between the lower and upper thresholds for an organism to develop from one stage of its life cycle to another, it provides an indicator system to assist farmers to select the most suitable genotypes or cultivars for their region (Patil *et al.,* 2014, Pallavi, 2018). Higher air temperature may lower spikelet fertility by decreasing the quantity of pollen deposited on the stigma(Pandey *et al.,* 2020, Thakur, 2022).

Grain sterility in rice is caused by high temperatures; spikelets become sterile after more than an hour of exposure to extreme heat (Weerakoon *et al.,* 2008). The indica and japonica strains did not differ as much. Cultivars with similar spikelet temperatures showed different heat tolerances due to differences in pollination capacity. High temperatures can lead to delayed germination, reduced pollen viability, and abnormal ovary development, and affect the accumulation of starch grains, among other phenotypes, thus affecting rice production (Afzal *et al.,* 2019, Liu *et al.,* 2024, Xin *et al.,* 2020, Zhao *et al.,* 2020). Also, there is a consensus in the literature that the synchronization of the critical phenophases with the favorable weather regime ensures a promising crop yield, which is only possible by adjusting the sowing date (Rani and Maragatham, 2013). (Shimono *et al.,* 2007) confirmed that low temperatures during vegetative growth also significantly increased sterility.

The growth and development of rice crops are significantly influenced by photoperiod, or daylight, and hours of intense sunshine. (Metwally *et al.,* 2016) reported that early sowing on the 10^{th} of April of some Egyptian rice genotypes produced better yield and yield attributes compared with late sowing dates. The temperature rising during the early season significantly shortens the rice vegetative phase in various sowing dates; the vegetative phase is more responsive to increased GDD than the reproductive stage (Promchote *et al.,* 2022). (Patel *et al.,* 2019) reported the days taken to reach flowering and harvest varied significantly among the sowing dates, the panicle initiation stage started late in the early sown crop and 50 percent flowering was earlier in the late crop, Experiments conducted at two locations showed that days from seedling emergence to 50 percent panicle emergence decreased at both locations as planting was delayed (Rani and Maragatham, 2013). Crop phenology can be used to specify the most appropriate date and time of a specific development process (Pandey *et al.,* 2020). Planting rice after the optimum dates can result in low yield due to environmental stress during heading and the grain filling period (Osman *et al.,* 2015). This study aims to examine the thermal requirements of a number of the local rice genotypes, growth physiology, and sterility through the adjustment of various sowing dates.

MATERIAL AND METHODS

A pot experiment was conducted in the plastic-house in the College of Agricultural Engineering Science- University of Sulaimani in 2024. Four rice genotypes were cultivated in three different sowing dates: April 21, May 11, and June 11. The rice genotypes include Japonica types (Banikhellan, Akre 1, and Akre 2, as well as one indica type, which was Sadry. The source of the Japonica genotypes' seeds was from reliable farmers, while the Sadry genotype originated from the Sulaimani Directorate of Agronomy Research. The experiment was laid out with a factorial Completely Randomized Design (CRD) with three replications. 108 pots with a 13 kg soil capacity were employed. Each pot measured 30 by 30 cm and was filled with a silty clay loam soil texture. To ensure the vitality of the seeds, all genotype seeds were tested for germination in the laboratory, and the germination evaluation was above 90%. The sowing process on the three planting dates of April 21, May 11, and June 11 was done by soaking the seeds of each rice genotype in water for 24 hours before sowing. 10 seeds were sown in each pot and then thinned to three seedlings. The plastic house was beneficial in the primary period from April to the Mid of May, protecting the small seedlings from stormy rain that usually recur at this time of year. The pots were supported with a drip irrigation system in addition to the manual supplementary irrigation as required. the fertilization was with NPK 14:14:14 as 22g pot^{-1} which half of this fertilizer was applied pre-seeding, and the second half was added after 65 days at active tillering (Liu *et al.,* 2024). A digital temperature and humidity data logger was fixed among the pots for registering the daily maximum and minimum temperature, as well as a light meter for registering the light intensity hourly from sunrise to sunset. Phenology characteristics were studied, such as the influence of three different sowing dates on the various growth stages, no. of days to 50% (tillering, Panicle initiation, Booting, Heading, Flowering, and physiological maturity). In addition to Sterility%, the studied reproductive criteria included No. of grains Plant^{-1}, 1000 grain weight, grain yield plant^{-1}, Plant biological yield, and harvest index. The relative rate of growth and development was evaluated through the determination of the rate of dry matter accumulation in different growth stages. To assign the most appropriate period of growth and development, the Growing degree days were determined from the sowing date to physiological maturity for diversified rice genotypes in varied sowing dates.

The Relative Growth Rate was calculated according to the following equation:

$$RGR\ g\ g^{-1}d^{-1} = \frac{lnW2 - lnW1}{t2 - t1} \text{ .... Mohammed, 2018 ... (1)}$$

Where: lnW2 is the natural logarithm of the plant weight at a later date, lnW1 is the natural logarithm of the plant weight at a previous date, t2 is the time 2 or later date, and t1 is the previous date.

The Growing Degree Day (GDD) was determined using a base temperature of 10 °C during the various crop growth stages for four rice genotypes. The accumulated thermal unit of different phenophases was calculated by using the following formula:

$$\text{GDD} = \frac{Tmax - Tmin}{2} - base\ temperature \ldots\ldots\ldots.\ Nandini\ and\ Sridhara, 2019 \ldots\ldots (2)$$

T_{max}, maximum daily temperature, T_{min}, minimum daily temperature. The base temperature for rice crops is 10 °C.

The sterility percentage was calculated for all rice genotypes according to the following equation:

$$Sterility\% = \frac{No.of\ infertil\ grain}{No.of\ fertil\ grain + No.of\ infertil\ grain} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots..\ldots Chen\ etal., 2017 \ldots..(3)$$

RESULTS AND DISCUSSIONS

Sowing Dates and accumulation of Growing Degree Days (GDD):

The phenology and thermal requirement of all rice genotypes were organized in Table 1, revealing the influence of different sowing dates (SD1, SD2, and SD3) in the accumulation of Growing Degree Days (GDD), due to the specific privilege daily temperature of these sowing dates on the growth physiology of rice genotypes that directly impacted the accumulation of heat units. Significant differences were displayed among rice genotypes in the number of days needed to pass or attain a certain growth stage (Malo and Ghosh, 2018). The highest number of days required to reach the panicle initiation (PI) was shown by the Sadry genotype in the three sowing dates, demonstrating (103.000, 92.667, and 84.333) days in SD1, SD2, and SD3, respectively. The minimum no. of days required for the panicle initiation stage was shown by the V2 genotype in the 1st and the 2nd sowing dates, while the V3 genotype (Akre 2) showed the lowest period to reach this stage in the 3rd sowing date, manifesting (91.33, 75.000, and 67.333) days. There was declining in the number of days to PI from the first to 2nd and 3rd sowing dates, the longest period to the PI was found in SD1 and the shortest period to PI was shown in SD3, there was decreasing in the GDD accumulation with the latter sowing date because of growth acceleration due to higher daily temperature, our outcomes were in line with (Chinmoy Halder *et al.,* 2010, Sreenivas *et al.,* 2010), and (Pandey *et al.,* 2020). The utmost amount of Growing Degree Days needed was in the coldest period of the 1st sowing date, which was between (1721.333 and 2268.317) GDDs, which declined toward SD2, and the minimal quantity was between (1583.083 and 1941.733) GDDs in SD3. The typical pattern was manifested in the decline in the no. of days and thermal requirement from SD1 to SD2 and SD3 in all other growth stages, booting, heading, flowering, and physiological maturity as illustrated in Table 1. Increased daily temperatures from April to May and June, when the three planting dates are consecutive, may hasten growth rates by completing the phenological stages earlier and accumulating less GDD. It has also been shown that higher daily temperatures shorten the growth stages (Rani and Maragatham, 2013). The accumulated crop heat units from the beginning of the growing seasons of SD1, SD2, and SD3 to physiological maturity (PM) were (3262.400, 3040.513, and 2595.338) GDD, respectively, the maximum GDD required by the earliest sowing date, while the latest date of sowing was with the minimum demand. Highly significant variations in the development and thermal necessity were shown among the four rice genotypes. The indica Sadry genotype prolonged the duration for starting a new growth stage, as well as entailed the highest amount of GDD. The total quantity of CHUs wanted to PM was (2905.483, 2900.989, 2868.278, and 3189.583) within the growing periods of (125.556, 124.444, 123.444, and 144.111) days achieved by V1, V2, V3, and V4 genotypes, respectively. Highly significant differences were found among the growing period of rice genotypes, the longest period to PM was performed by indica genotype (V4) which interacted with the effect of SD1 revealing(144.111) days with 3189.583 GDD, whereas the shortest duration was shown under the influence of SD3V3 interaction by Akre2 genotype (V3) which was (123.444) day through accumulating 2868.278 GDD, Lower daily temperatures on the first sowing date resulted in longer growth phenophase durations for rice genotypes, especially the Sadry genotype.

This may have been due to genotype adaptation, and the study's findings are consistent with those of (Rajesh Khavse *et al.,* 2015, Metwally *et al.,* 2016)&(Deshmukh *et al.,* 2021).

Table (1), Influence of sowing dates and rice genotypes and their interaction on the number of days and accumulated GDD required for attaining different growth stages

	Panicle initiation		Booting		Heading		Flowering		PM	
	No. of days	GDD	No. of days	GDD	No. of days	GDD	No. of days	GDD	No. of days	GDD
SD1	95.083	2029.129	99.417	143.500	103.500	2279.26	106.083	2336.59	143.500	3262.400
SD2	80.750	1926.317	84.000	130.250	87.083	2067.39	90.333	2139.42	130.250	3040.513
SD3	74.083	1721.763	77.083	114.417	81.000	2114.99	83.000	1872.6	114.417	2595.338
L.S.D 0.05	2.620	119.430	3.002	0.743	3.254	125.582	3.311	95.7711	0.743	13.488
L.S.D 0.05	3.550	161.848	4.068	1.007	4.410	170.185	4.487	129.786	1.007	18.278
V1	79.111	1739.617	81.667	125.556	84.889	2012.07	87.444	2003.81	125.556	2905.483
V2	79.333	1823.033	82.333	124.444	85.556	2027.09	88.111	2016.51	124.444	2900.989
V3	81.444	1873.017	85.222	123.444	90.111	2263.11	91.889	2055.16	123.444	2868.278
V4	93.333	2133.944	98.111	144.111	101.556	2313.26	105.111	2389.34	144.111	3189.583
L.S.D 0.05	3.0250	137.906	3.466	0.858	3.758	145.009	3.824	110.587	0.858	15.574
L.S.D 0.01	4.0994	186.886	4.698	1.163	5.092	196.512	5.182	149.864	1.163	21.106
S1V1	89.333	1721.333	91.333	138.333	94.333	2074.53	97.000	2133.78	138.333	3186.200
S1V2	91.333	2000.600	94.333	137.333	96.333	2119.27	98.667	2171.12	137.333	3178.750
S1V3	96.667	2126.267	103.000	139.667	109.667	2416.75	111.667	2461.12	139.667	3196.267
S1V4	103.000	2268.317	109.000	158.667	113.667	2506.48	117.000	2580.35	158.667	3488.383
S2V1	75.333	1805.733	77.667	123.667	80.333	1917.35	83.333	1984	123.667	2941.167
S2V2	75.000	1798.050	78.000	123.667	81.000	1932.17	84.667	2013	123.667	2935.133
S2V3	80.000	1909.700	82.333	126.000	86.667	2058.12	88.333	2095.42	126.000	2941.167
S2V4	92.667	2191.783	98.000	147.667	100.333	2361.92	105.000	2465.25	147.667	3344.583
S3V1	72.667	1691.783	76.000	114.667	80.000	2044.32	82.000	1893.63	114.667	2589.083
S3V2	71.667	1670.450	74.667	112.333	79.333	2029.83	81.000	1865.4	112.333	2589.083
S3V3	67.667	1583.083	70.333	104.667	74.000	2314.45	75.667	1608.93	104.667	2467.400
S3V4	84.333	1941.733	87.333	126.000	90.667	2071.37	93.333	2122.42	126.000	2735.783
L.S.D 0.05	5.239	238.860	6.004	1.486	6.508	251.163	6.623	191.542	1.486	26.976
L.S.D 0.01	n. s	323.696	n. s	2.014	n. s	340.369	n. s	259.573	2.014	36.556

Note: SD1: First Sowing Date (April21), SD2: Second Sowing Date (May 11), SD3: Third Sowing Date (Jun11), V1: Banikhellan rice genotype, V2: Akre1 rice genotype, V3:Akre2 rice genotype, V4: Sadry indica rice genotype

Dry Matter Accumulation:

The total dry matter accumulation (g $plant^{-1}$) varied considerably under the influence of the three planting dates, depending on the distinct growing conditions created by the sowing dates.

Under the SD1 climatic conditions, Fig. 1, A.B.C.D, and Fig. 2 display a slow accumulation of total dry matter and a smaller Relative Growth Rate for all rice genotypes due to lower daily temperature means in April and May. There was an acceleration in the accumulation of dry weight of all rice genotypes with the impact of SD2 and SD3 from the seedling to the booting stage. The dry matter accumulation process for all varieties showed a significant increase on the second and third dates. The highest performance for all varieties was on the third date, except for the third genotype (Akre 2), which showed maximum potential on the second date. Fig.2 displays the RGR of all rice genotypes in the three sowing dates that were on the rise from the seedling to the booting stage. The performance of Banikhellan genotype V1 was (3.855, 9.345, 9.685) g g^{-1} d^{-1} in (SD1, SD2, SD3) respectively, while the RGR of 2nd genotype during the same period (from seedling to the booting stage) was (3.14, 8.1, 9,1) g g^{-1} d^{-1} in (SD1, SD2, SD3), however the genotype V3 (Akre 2) showed elevated dry matter accumulation in SD2 and SD3 with highest achieving at SD2, the RGR of this genotype from the seedling to booting stage was (3.155, 10.85, 11.225) g g^{-1} d^{-1} in (SD1, SD2, SD3) respectively. The RGR of the 4th genotype (Sadry) in three variant sowing dates (SD1, SD2, and SD3) was (2.29, 5.95, and 13.9) g g^{-1} $d^{-1,}$ respectively; the highest rate of growth was at the third sowing date. There is a clear indication between the increase in growth and development of the rice genotypes represented by the accumulation of the highest rate of dry matter or high rate of relative growth on the one hand, and the suitability for the three planting dates on the other hand, the consequence agrees with (Matsui *et al.,* 2001, Sultana *et al.,* 2019) whom they confirmed that dry matter accumulation depends on genetic factors and sowing time while the suitable temperature had a large effect on dry-matter accumulation in the early growth stages. There were distinctions between Indica and Japonica cultivars; however, these variations were mostly based on each cultivar's agronomic traits (Pallavi, 2018). The good results of the rice genotypes 1 and 2 (Banikhellan and Akre 1) show their suitability for the first date in the Sulaymaniyah region (Fig.1, A&B), on the other hand, the third rice genotype 3 showed higher efficiency in growth in the second date (Fig.1, C), as for the fourth genetic composition, Sadry, the increase in the accumulation of dry matter or the high rate of relative growth rate confirms the success of its cultivation in the third sowing date or at least the genotype active growth should synchronize with this sowing date Fig.1, D & Fig.2.

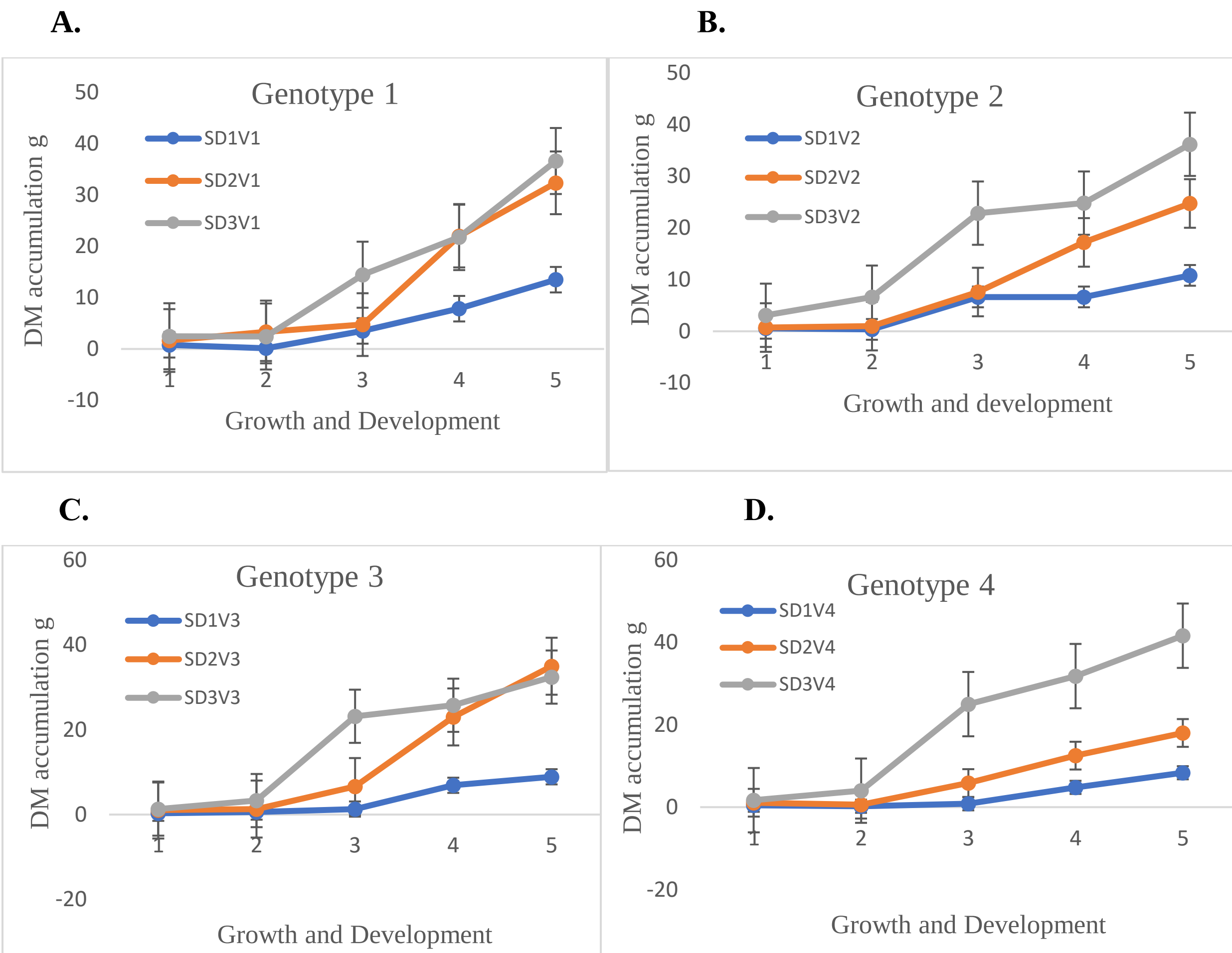


Fig. (1) Dry matter accumulation of rice genotypes, Banikhellan A., Akre1 B., Akre 2 C., Sadry D., along the growing season of different sowing dates SD1, SD2, and SD3

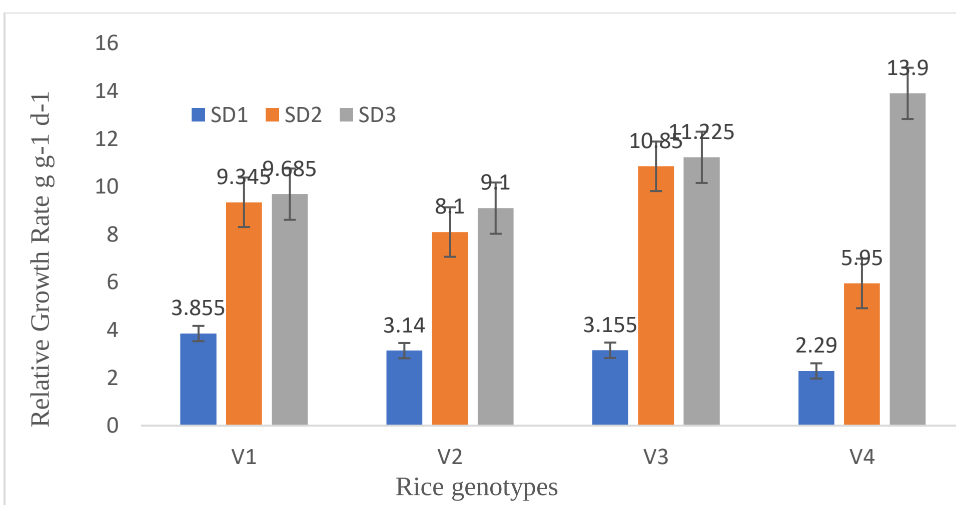


Fig. (2) Relative Growth Rate of rice genotypes from seedling to Panicle initiation in different sowing dates, SD1, SD2, and SD3

Yield and Yield Component:

The grain yield of different rice genotypes showed significant variation under cultural conditions supplied by different sowing dates. Some relative criteria to the yield and yield components were presented in Table 2, significant variation was found in the effect of sowing dates in the number of seed plant^{-1}, 1000 grain weight, and biological yield g in which the superiority was to 1st sowing date versus other sowing dates demonstrating (2621.000, 31.327 g, and 132.981g), while the influence of SD2 and SD3 for these important yield components were (2169.583, 30.643 g and 107.986g), and (1810.500, 29.173g, and 91.398g) respectively. Significant exceeding of 1st sowing date SD1 in grain yield plant^{-1} with 55.284g was demonstrated versus other sowing dates SD2 and SD3, displaying (45.847, and 36.744) g. Variations in the climatic conditions of three sowing dates, especially the moderate temperature mean in the 1st sowing date, may cause a boost in the net assimilation rate due to efficient photosynthesis and a decline in the rate of respiration that accretes the sink supplement(Mohammed *et al.,* 2011, Xie *et al.,* 2011)&(Pallavi, 2018)The previous research confirmed that higher yield could be the effect of temperature, radiation, or photoperiod on phenological fulfillment (Sultana *et al.,* 2019). Grain yield was positively and significantly correlated with dry matter accumulation efficiency (Ntanos and Koutroubas, 2002). Considerable statistical variation was manifested among four rice genotypes in the yield and yield component criteria No. of seed plant^{-1}, 1000 grain Wt., grain yield plant^{-1}, and Harvest index. The Banikhellan genotype (V1) surpassed other genotypes in No. of seed plant^{-1} and grain yield plant^{-1} producing (2845.222, 56.001g), while the maximum 1000 grain weight. recorded by V3 and maximum HI was preceded by V2 (0.472). Minimum value of No. of seed, Plant^{-1} was gained by V3 (1679.667), while the minimum value of 1000 grain Wt., grain yield, and harvest index was obtained with the 4th rice genotype performance (26.982g, 29.619g, and 0.272), respectively. Differences in rice genotypes' performance may result from their capabilities to adapt to sowing date circumstances(El-Ramady *et al.,* 2013, Manoj Kandel *et al.,* 2018, Promchote *et al.,* 2022, Das *et al.,* 2024) or compensations between yield components, always arising from either physiological competition or developmental determination(Huang *et al.,* 2016).

Table (2), Influence of three sowing dates and rice genotypes on the Grain yield and Yield components of four rice genotypes

Treatments	no. of seed Plant $^{-1}$	1000 grain Wt. g	Biological Yield g	Grain Yield g plant $^{-1}$	HI
SD1	2621	31.327	132.981	55.284	0.416
SD2	2169.583	30.643	107.986	45.847	0.411
SD3	1810.5	29.173	91.398	36.744	0.402
L.S.D 0.05	503.947	1.472	26.741	11.866	n.s
L.S.D 0.01	682.935	1.995	36.239	16.081	n.s
V1	2845.222	29.498	121.861	56.001	0.460
V2	2512.222	30.262	113.155	53.740	0.472
V3	1764.333	34.782	104.903	44.472	0.436
V4	1679.667	26.982	103.233	29.619	0.272
L.S.D 0.05	581.908	1.700	n. s	13.702	0.062

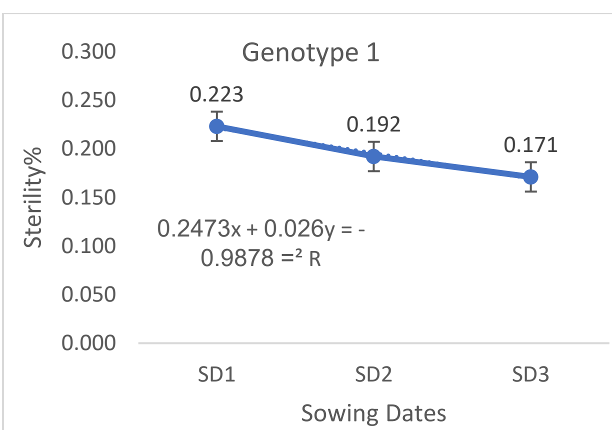
Note: Note: SD1: First Sowing Date (April21), SD2: Second Sowing Date (May 11), SD3: Third Sowing Date (Jun11), V1: Banikhellan rice genotype, V2: Akre1 rice genotype, V3:Akre2 rice genotype, V4: Sadry indica rice genotype

Sterility%:

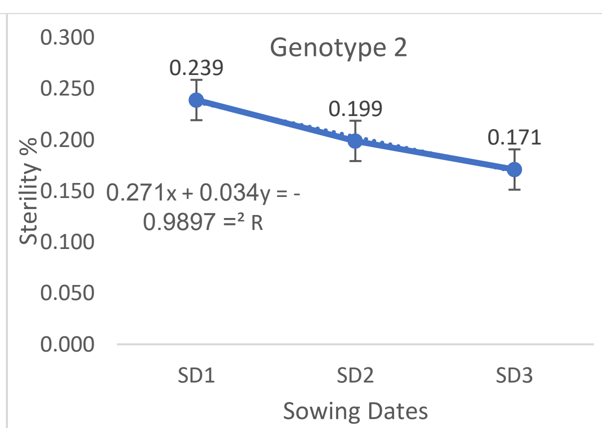
The response of rice genotypes was illustrated in the Fig. 3 revealing similarity in producing infertile grains by genotypes V1 and V2 in different three sowing dates (Fig.3, A&B) in which there was a slight decline in the sterility from SD1 to SD2 and SD3 manifesting (0.223, 0.192, and 0.171) by first genotype V1 and performance of V2 was (0.239, 0.199, and 0.171) respectively, while the 3rd genotype (Akre 2) showed boosting in the sterility in SD1 (0.307) and then sharply descended toward SD2 and SD3 displaying (0.235, and 0.077) as illustrated in Fig.3, C. The performance of the Sadry genotype to environmental conditions provided by three sowing dates (SD1, SD2, and SD3) was with a higher percentage of sterility in SD1(0.340), and raised to the highest level (0.420) in SD2 and then declined to lower level (0.333) in SD3 (Fig.3, D). There was a high correlation between sterility% and environmental conditions, especially ambient temperature provided by variant sowing dates; the R-squared value was (0.98, 0.98, 0.95, and 1.00) for rice genotypes (V1, V2, V3, and V4), respectively. However high temperature-induced grain sterility in rice, the physiological analysis of sterility was done by previous researchers that the main cause of sterility was a failure of fertilization, as well as differences between japonica and indica rice genotypes and the degree of influence depends on the nature of rice varieties in which divided to tolerant, moderate and sensitive (Matsui *et al.,* 2001, Maruyama *et al.,* 2013).

The effect of the interaction between the impact of different sowing dates and the response of rice genotypes was illustrated in Fig. 4, demonstrating the sterility% of 1st and 2nd rice genotypes while interacting with the effect of SD1, SD2, and SD3, the lowest sterility percentage of both genotypes V1 and V2 were found with the effect of third sowing dates demonstrating the same percentage 0.171, while the performance of these two genotypes when interacted with SD1 and SD2 were 0.223 and 0.192 for the genotype Banikhellan (SD1V1) and 0.223 and 0.199 for Akre1 genotype in the interactions (SD1V2 and SD2V2). The efficiency of the 3rd rice genotype was raised with the interaction with the 3rd environmental conditions, which revealed the minimum percentage of sterility (0.007) achieved by this genotype compared with its interaction with SD1(0.307) and SD2 (0.235). Compared to the japonica genotypes, the achievement of the indica genotype Sadry showed inefficiency for adaptation and thus the highest sterility% when interacted with the climatic status provided by three different sowing dates SD1V4, SD2V4, and SD3V4, displaying (0.34, 0.42, and 0.333) respectively. The degree of tolerance of rice genotypes correlated with the suitability of various sowing dates for cultivation, especially the better performances of genotypes V1 and V2 in SD2 and SD3, as well as the performance of V3 in the third sowing date. The moderate climate conditions in June and September, which synchronize with the anthesis stage, as well as the capability of japonica genotypes for adaptation and tolerance, may be considered for better performance of those genotypes. Our findings are consistent with (Matsui *et al.,* 2001, Weerakoon *et al.,* 2008, Patel *et al.,* 2019).

A.



B.



C. **D.**

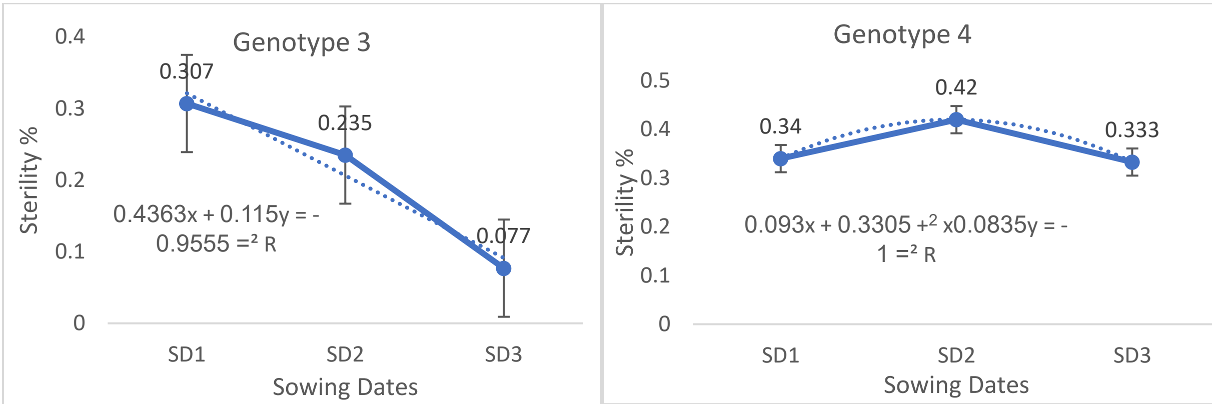


Fig. (3) Sterility % of rice genotypes in different sowing dates, A. Banikhellan, B. Akre 1, C. Akre 2, and D. Sadry genotype

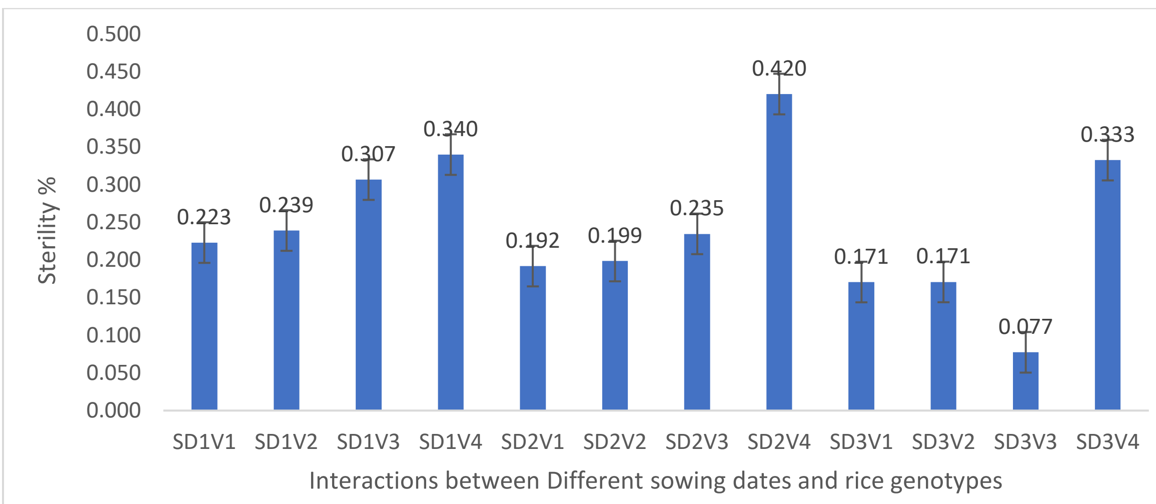


Fig. (4) Effect of Interaction between different sowing dates (SD1, SD2, and SD3) and responses of rice genotypes on Sterility%

CONCLUSIONS

A significant determinant of rice growth and development, sterility, and yield is temperature. The privileged temperature during the growing season influenced the number of days required from emergence to panicle initiation, booting, heading, flowering, and physiological maturity through shortening and extending certain stages or attaining a new stage. The proper date of rice sowing provides the favorable heat requirements of rice genotypes, especially synchronization of the flowering stage, which effectively contributes to rice development and its output. While the first and second genotypes benefited from the growing circumstances of the first and second sowing dates, the third genotype found the second and third dates more convenient, whereas the indica rice was not authorized for the two sowing dates. A higher sterility percentage rate, which is thought to significantly influence production, was created by unfavorable anthesis conditions, particularly high temperatures. This influenced the rice genotypes included in the study, with the fourth genotype having the highest sterility percentage, reaching 42%. As a result, the indica genotype Sadry performed better under SD3 conditions, while the japonica genotypes, except Akre2, had appropriate planting dates of SD1 and SD2. Under environmental restrictions, the Akre2 genotype's short growth period, compared to others, can be utilized to yield more rice.

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