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Effect of sowing time on phenological development and productivity of pulses: A review

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Abstract
Pulses play a crucial role in ensuring nutritional security, soil fertility improvement, and sustainable agricultural production, particularly in tropical and subtropical regions. Among the various agronomic practices, sowing window is a critical non-monetary factor that governs crop exposure to prevailing weather conditions and significantly influences phenological development and productivity of pulse crops. This review synthesizes research findings from diverse agro-climatic regions to elucidate the effects of sowing time on growth parameters, phenology, yield attributes, yield, quality, nutrient uptake, agro-meteorological indices, soil nutrient status and economics of major pulse crops such as greengram, mungbean, blackgram, chickpea, pigeonpea, cowpea and horsegram. The reviewed studies consistently demonstrate that timely or optimum sowing ensures better synchronization of crop growth stages with favourable temperature, radiation and moisture regimes, resulting in enhanced plant height, leaf area index, dry matter accumulation, nodulation and improved reproductive efficiency. Optimum sowing windows also promoted favourable agro-climatic indices such as growing degree days, photo-thermal units and helio-thermal units, thereby improving yield attributes including pods plant^{-1}, seeds pod^{-1}, test weight and ultimately seed and haulm yields. In contrast, delayed sowing often exposed crops to terminal heat stress, shortened growth duration and suboptimal thermal environments, leading to reduced productivity and economic returns. Timely sowing was also associated with improved nutrient uptake efficiency and, in some cases, better post-harvest soil nutrient status. Overall, the review highlights that identification and adoption of location-specific optimum sowing windows, integrated with weather-based planning and varietal suitability, can serve as a climate-smart strategy to enhance productivity, profitability, and sustainability of pulse-based cropping systems.

Keywords: Agro-meteorological indices, nutrient uptake, phenology, productivity, pulses and sowing window

Introduction
Pulses plays a vital role in Indian agriculture by enriching soil fertility, contributing to nutritional security and offering livelihood opportunities to millions of smallholder farmers. Among pulses, crops like greengram, mungbean, blackgram, chickpea and pigeonpea are widely cultivated across diverse agro-climatic zones. The productivity and efficiency of these crops are significantly influenced by the sowing time, which determines the crop's exposure to prevailing meteorological conditions and soil health status. Time of sowing plays a key role in how well these crops grow and produce yield. It affects the temperature and daylight the crop receives, which in turn influences plant growth, flowering, seed development and nutrient use. Research from across India and other countries has shown that sowing at the right time leads to better plant height, leaf growth, dry matter production, pod and seed development and improved soil after harvest. Sowing time also impacts important weather-based measures like growing degree days, photo-thermal units and helio-thermal units, which help crops grow in suitable conditions. This review brings together findings from many studies to explain how sowing dates affect the growth, yield, nutrient uptake and economics from pulse crops.

Growth Parameters
Plant height
Togay *et al*. (2014) [61] registered significantly taller plants of cowpea when the crop was sown on 15 th April compared to that of 30 th April and 15 th May on sandy loam soils of Mardin, Turkey. The research conducted by Palsaniya *et al.* (2017) [41] concluded that significantly higher plant height of mungbean was observed at 60 DAS with 20 th April and 5 th May sowing dates during summer season on sandy clay loam soils of Jammu, Chatha. Gurjar *et al.* (2018) [19] reported that sowing of semi rabi greengram on 3 rd week of September recorded significantly higher plant height on sandy loam soils of Anand Agricultural University, Gujarat. A field experiment was conducted at Agricultural Research Station, Madhira, Telangana found that the tallest plant stature of greengram was recorded when sowing was done on 3 rd week of June followed by 1 st week of July during kharif season (Rao *et al*., 2018) [47]. Sowing of greengram on 1 st fortnight of July recorded maximum plant height during kharif season on sandy loam soils of Prayagraj, U.P (Charan *et al*., 2024) [9].

Leaf area index
Kumar and Kumawat (2014) [26] reported that higher leaf area index of mungbean was recorded with 5 th April sown crop and significantly superior over 15 th April sown crop during summer season on sandy loam soils of Jharnapani, India. A field experiment conducted at Punjab, Ludhiana during kharif season and revealed that sowing of mungbean on 16 th July attained significantly higher leaf area index on loamy sand soils (Gill *et al*., 2018). Ahmed *et al*. (2023) [1, 16] found that significantly higher leaf area index of greengram was recorded, when the crop was sown on 1 st

September compared to other sowing dates during kharif season on clay loam soils of Assam, India. A field experiment conducted by Neog *et al.* (2025) [38] during summer season concluded that greengram crop sown on 20 th March resulted in higher leaf area index at Assam Agricultural University, Jorhat.

Dry matter production

Neenu *et al*. (2017) [37] reported that dry matter production was significantly higher with 1 st fortnight of November compared to 2 nd fortnight of November sown chickpea during rabi season on black soils of Indian Institute of Soil Science, Bhopal, India. Bobade *et al*. (2018) [8] reported that sowing of greengram on 23 rd June recorded significantly higher dry matter plant -1 over 30 th June during kharif season at Parbhani, Maharashtra.A field experiment conducted at Punjab Agricultural University, Ludhiana during kharif season revealed that sowing of mungbean on 16 th July attained significantly higher values of dry matter production on loamy sand soils (Gill *et al*., 2018) [16]. Higher dry matter production of greengram was recorded when the crop was sown during 3 rd week of June followed by 1 st week of July during kharif season at Agricultural Research Station, Madhira, Telangana (Rao *et al*., 2018) [47].The research conducted by Niveditha *et al*. (2024) [40] revealed that early sowing of chickpea during the I st fortnight of October resulted in higher dry matter accumulation on black soils of Karnataka, India.

Number of branches plant -1

Jahan and Adam (2012) [21] noticed maximum number of branches plant -1 when mungbean was sown on 15 th April as compared to that of 15 th March and 15 th May on clay loam soils of Dhaka, Bangladesh. Singh *et al.* (2018) [12] recorded higher number of branches plant -1 of mungbean sown on 30 July during kharif season on loamy sand soils of Punjab Agricultural University, Ludhiana. A field experiment was conducted by Pamei *et al*. (2020) [42] observed that number of branches plant -1 were higher with 15th March sown mungbean crop during summer season on clay soils of Central Agricultural University, Imphal. The number of branches plant -1 was gradually increased due to delay in sowing from 15 th February to 4 th April during summer season on loamy soils of Jaguli, West Bengal (Kundu *et al.,* 2021) [31]. The research work conducted by Gorai and Mondal (2023) [17] revealed that significantly higher number of branches plant -1 of mungbean was recorded when sowing was done on 26 th March over 16 th March during pre-kharif season on silty loam soils of Birbhum, West Bengal.

Days to 50 per cent flowering

Singh *et al.* (2012) [23] noticed that urdbean sown on 5 th August reached 50 per cent flowering earlier compared to the crop sown on 5 th July on loamy sand soils of Ludhiana, Punjab. The mungbean crop sown on I st fort night of June took more number of days to attain 50 per cent flowering over I st fort night of July and on par with II nd fort night of June during kharif season on clay soils of University of Agricultural Sciences, Dharwad (Madhu *et al.*, 2014) [32]. The highest number of days for 50 per cent flowering was observed with 30 th June sown greengram crop during kharif season at Parbhani, Maharashtra (Bankar *et al*., 2020) [5]. More number of days to attain 50 per cent flowering in blackgram was noticed when the crop was sown during first week of March compared to that of third week of March on clay loam soils of Nadia, West Bengal (Benerjee *et al*., 2021) [6].

Number of nodules plant -1

The highest number of nodules plant -1 was recorded when greengram was sown on June 25 th during kharif season on sandy loam soils of Modipuram, Meerut, Uttar Pradesh (Singh *et al*., 2013) [53]. A field experiment was conducted during summer season at Jhansi, U.P. The experiment revealed that mungbean sown on 26 th March produced maximum number of nodules plant -1 and it was significantly comparable to the other treatments on sandy loam soils (Kumar *et al.,* 2016). Pamei *et al*. (2020) [25, 42] concluded that higher number of nodules plant -1 was recorded with the crop sown on 15 th March during summer season on clay soils of Central Agricultural University, Imphal. Charan *et al*. (2024) [9] reported that significantly higher number of nodules plant -1 was observed with 1 st fortnight of July sown mungbean at 60 DAS during kharif season on sandy loam soils of Prayagraj, U.P.

Yield Attributes

Number of pods plant -1

Number of pods plant -1of mungbean was significantly higher when the crop was sown on March 12 th compared to February 20 th during spring season on silty clay loam soils of Uttarakhand (Kumar *et al*., 2012).Prasad *et al.* (2012) [23, 43] conducted a field experiment at Hisar, Haryana and the results revealed that December 1 st sowing produced significantly maximum number of pods plant -1 than other sowing dates (10 th and 20 th December) in chickpea. Number of pods plant -1 of mungbean was significantly higher with early sowing (2 nd fortnight of June) compared to other sowing times during kharif season on sandy loam soils of Hisar, India (Dhaka *et al*., 2018) [12]. The experiment was carried out by Singh *et al.* (2019) [56] during kharif season stated that greengram sown on 1 st April produced higher number of pods plant -1 than other sowing dates at Talwandi, Punjab on sandy loam soils. Bankar *et al*. (2020) [5] reported that the maximum number of pods plant -1 of greengram was observed when sowing was done on 16 th June during kharif season at Parbhani, Maharashtra. A field experiment was conducted by Kumar *et al*. (2022) [24] during kharif season on sandy clay loam soils concluded that maximum number of pods plant -1 of pigeonpea was recorded in July 1 st sown crop at Palem, Telangana.

Number of seeds pod -1

Kumar *et al.* (2010) [28] reported that significantly higher number of seedspod -1 of mungbean was recorded with the crop sown on 25 th March during summer season on sandy loam soils of Bihar, India. Mungbean crop sown on 25 th June produced significantly higher number of seeds pod -1 over other sowing dates during kharif season at College of Agriculture, Badnapur (Mule *et al*., 2020). Ranjan *et al*. (2020) [35, 45] observed that higher number of seeds pod -1 was attained when greengram was sown on 19 th February during rabi season on sandy loam soils of Bhubaneswar, Odisha. Field experiment was carried out by Bag *et al*. (2020) [4] during pre-kharif season at Kalyani, West Bengal revealed that maximum number of seeds pod -1 was observed when mungbean was sown on 22 nd March when compared to 3 rd March. In a field experiment conducted at

Kovilpatti, Tamil Nadu, it was revealed that number of seeds pod $^{-1}$ of greengram was significantly higher with the crop sown during last week of September during rabi season (Subbulakshmi, 2021) [57].

Pod length

Kumar *et al.* (2010) [28] recorded higher pod length of mungbean, when the crop was sown on 25 th March during summer season on sandy loam soils of Bihar, India. Jahan and Adam (2012) [21] reported that mungbean sown on 15 th April recorded significantly higher pod length than other sowing dates at Dhaka, Bangladesh. Blackgram crop sown at 20 days after onset of monsoon *i.e.*10 th July recorded the maximum pod length which was significantly superior over rest of sowing dates (Gadpale, 2013) [13]. Gangwar *et al.* (2013) [14] concluded that pod length was increased with delay in planting of urdbean upto March 20th during summer season at Pantnagar, Uttarakhand. Sowing of mungbean on March 30 th resulted in significantly the longer pods at Chitwan, Nepal (Neupane *et al*., 2023) [39].

Pod weight plant $^{-1}$

Significantly higher weight of pods plant $^{-1}$ was observed in 14 th September sown horsegram than other sowing dates during post kharif season on sandy clay soils of Chhattisgarh, India (Sahu *et al*., 2021). Maximum weight of pods plant $^{-1}$ of chickpea was recorded when the crop was sown on September 17-23 during rabi season on black soils of Solapur, Maharashtra (Rathod *et al*., 2024) [48]. Significantly higher pod weight was recorded in early sown (May 15 th to 30 th) pigeonpea during kharif season at GKVK, Bengaluru (Thimmegowda *et al*., 2024) [58]. Mungbean sown during 3 rd metereological week (15-21 January) produced significantly superior weight of pods than the rest of the sowing windows during rabi season on sandy clay loam soils of Kolhapur, Maharashtra (Jadhav *et al*., 2025) [20].

Thousand seed weight

Rehman *et al*. (2009) [50] reported that the maximum test weight of mungbean was recorded in 30 th March sown crop during summer season at Peshawar. An experiment was carried out by Meena *et al.* (2017) [33] during *zaid* season reported that maximum seed index was recorded under sowing of greengram on 15 th March and at par with 25 th March in the pooled analysis at Banswara, Rajasthan. Higher thousand seed weight of munbean was recorded in early sown crop *i.e.* 2 nd fortnight of June compared to other sowing times during kharif season on sandy loam soils of Hisar, India (Dhaka *et al*., 2018) [12].Mungbean crop sown on 25 th June produced significantly higher thousand seed weight over other sowing dates during kharif season at College of Agriculture, Badnapur (Mule *et al*., 2020) [35]. Thousand seed weight of mungbean was higher with 15 th March sown crop during summer season on clay soils of Central Agricultural University, Imphal (Pamei *et al.,* 2020) [42].

Yield

Seed yield

Significantly higher seed yield of greengram was recorded when sowing was done on March 30 th during summer season at Faizabad, Uttar Pradesh (Ram and Dixit, 2001) [44].Sowing of semi rabi greengram on 3 rd week of September recorded significantly higher grain yield on sandy loam soils of Anand Agricultural University, Gujarat (Gurjar *et al.,* 2018). Annie *et al*. (2020) [2, 19] recorded higher seed yield of greengram was recorded with the crop was sown on 25 th August during kharif season at Assam Agricultural University, Jorhat. Ghosh *et al*. (2020) [15] conducted an experiment on loamy sand soils of West Bengal, India during pre-kharif season and the results revealed that the highest seed yield of greengram was recorded when the crop was sown on 1 st March. In a field experiment conducted at West Bengal, India during *pre*-kharif season (February-May) and noticed that greengram sown on 1 st March produced the highest grain yield, being at par with 15 February on loamy soils (Kumar and Rajput, 2020) [29]. An experiment was conducted by Sandhu and Singh (2020) [2] during kharif season at Ludhiana, Punjab observed that higher seed yield of mungbean was observed with 15 th July sown crop followed by 1 st July and 30 th July sown crop.

Haulm yield

Tiwari and Meena (2014) [60] conducted an experiment at Varanasi, Uttar Pradesh on sandy clay loam soils during rabi season and observed that early sowing of chickpea *i.e.*10 th November produced maximum haulm yield compared to delayed sowings (25 th November and 5 th December. The crop sown on 23 rd June produced maximum haulm yield of greengram which was significantly superior over rest of the sowing dates during kharif season at Parbhani, Maharashtra (Bobade *et al*., 2018) [8].Sowing of semi rabi greengram in 3 rd week of September recorded significantly higher haulm yield at Anand Agricultural University, Gujarat on sandy loam soils (Gurjar *et al.,* 2018). Ashwini *et al*. (2021) [3, 19] reported that sowing of greengram on 15 th July resulted in significantly higher haulm yield during kharif season on sandy loam soil of Shivamogga, Karnataka. Gupta *et al*. (2024) [18] concluded that timely sowing (27 th June) of urdbean recorded significantly the highest straw yield of urdbean during kharif season at Chhattishgarh, India.

Quality

Protein Content

Sowing time failed to exert a significant effect on the protein content of cluster bean during summer season on clay soils of Navsari, Gujarat (Vishal and Swapnil, 2015). Biswas *et al*. (2024) [7, 63] concluded that the highest protein content of greengram was recorded in the crop sown on 12 th February which was at par with 5 th March during summer season at Bhubaneswar, Odisha. A field experiment was conducted by Dash *et al*. (2024) [10] during kharif season noticed that the highest protein content of pigeonpea was recorded when the crop was sown during I st fortnight of May on red sandy loam soils of GKVK, Bengaluru.

Meteorological Indices

Growing degree days

In a field experiment conducted in black soils of Dharwad, Karnataka it was observed that temperature regime at 45 th standard week recorded significantly higher growing degree days for 50% flowering in chickpea compared to other sowing dates (Kiran and Chimmad, 2018) [22]. Ransing *et al*. (2014) [46] noticed that there was reduction in accumulation of growing degree days to reach maturity in mungbean when sowing was done on July 20 th during Kharif season.

Bankar *et al*. (2020) [5] noticed that greengram accumulated more growing degree days for attaining various phenophases when sowing was done on 16 th June over rest of the sowing dates during kharif season at Parbani, Maharashtra. In a field experiment conducted during kharif season at Ludhiana, Punjab and it was observed that early sown (1 st July) mungbean crop had accumulated maximum number of growing degree days at all the phenological stages as compared to late sown (30 th July) crop (Sandhu and Singh, 2020) [2].

Photo-thermal units

Singh *et al*. (2012) [23] concluded that urdbean sown on 5 th July accumulated more photo thermal units when compared to 5 th August sown crop on loamy sand soils of Ludhaina, Punjab. Bankar *et al*. (2020) [5] reported that greengram accumulated more photo thermal units for attaining various phenophases when sowing was done on 16 th June over rest of the sowing dates during kharif season at Parbani, Maharashtra. Kumari (2023) [30] conducted a field experiment during kharif season at Hisar, India and the results revealed that photo thermal units were attained maximum at physiological maturity when the greengram was sown on II[nd] fortnight of June.

Helio thermal units

Early sown mungbean crop *i.e.,* 2 nd fortnight of June recorded significantly higher accumulation of helio thermal units upto maturity during kharif season on sandy loam soils of Hisar, India (Dhaka *et al*., 2018). Thombre *et al.* (2019) [12, 59] executed a field experiment at Akola during rabi season and observed that early sown chickpea crop requires more helio thermal units as compared to normal and late sown crop which indicates that the helio thermal units were the highest in first sowing date (15 th November) followed by delayed sowing dates (30 th November, 15 th December and 30 th December).Annie *et al*. (2020) [2] noticed that there was decrease in helio thermal units accumulation for all growth phases of greengram from 25 th August to 25 th September during kharif season on sandy loam soils of Jorhat, Assam.

Nutrient Uptake

Significantly higher nutrient (N, P and K) uptake of mungbean was recorded when the crop was sown on June 25 th as compared to remaining sowing dates during kharif season at Meerut, Uttar Pradesh (Singh *et al.,* 2013). Palsaniya *et al*. (2017) [41, 53] reported that no significant difference was found with respect to nutrient (N, P and K) uptake by mungbean crop under different sowing dates on sandy clay loam soils of Jammu & Kashmir. A field experiment was conducted at S. V. Agricultural College, Tirupati during rabi season on sandy clay loam soils revealed that the higher nutrient (N, P and K) uptake of pigeonpea was recorded when the crop was sown during II fortnight of September (Nagamani *et al*., 2020) [36]. The present study was undertaken by Mobeena *et al.* (2022) [34] during summer season on sandy loam soils of S. V. Agricultural College, Tirupati found that early sown crop *i.e*. during I st fortnight of January recorded higher nutrient uptake of fodder cowpea at harvest.

Post-Harvest Soil Nutrient Status

Kumar *et al*. (2015) [27] reported that available nitrogen, phosphorus and potassium content in the soil was not significantly influenced by times of sowing of summer mungbean on sandy loam soils of Jharnapani, Nagaland. Fodder cowpea sown during I st FN of February recorded higher post-harvest soil available nitrogen, phosphorus and potassium which was on par with that of II FN of January sowing during summer season on sandy loam soils of S. V. Agricultural College, Tirupati (Mobeena *et al*., 2022) [34].

Economics

Kumar *et al*. (2015) [27] obtained maximum gross, net returns and B:C ratio on 5 April sown mungbean crop during summer season on sandy loam soils of IARI, New Delhi. Reddemma (2018) [49] noticed that blackgram crop sown on 1 st fortnight of October achieved higher gross, net returns and B:C ratio during rabi season on sandy loam soils of Agricultural College, Mahanandi. Thombre *et al.* (2019) [59] observed that higher gross, net returns and B:C ratio were recorded when chickpea crop was sown during 15 th November over rest of the sowing dates during rabi season on clay soils of Akola. In a field experiment conducted at Satna, Madhya Pradesh it was observed that higher net returns and B:C ratio were recorded when greengram crop was sown during 1 st week of July (Vaishya and Lilhare, 2022) [62].Sowing of greengram on 26 th metereological week recorded significantly higher gross, net monetary returns and B:C ratio and it was at par with the crop sown on 27 th metereological week during kharif season on clay soils of Nagpur (Deshmukh *et al*., 2024) [11].

Conclusion

The reviewed studies clearly indicate that optimum sowing windows ensure synchronization of crop phenology with favourable environmental conditions, leading to better vegetative growth, higher dry matter accumulation, enhanced reproductive successand improved yield potential. Early or timely sowing often results in increased growth parameters and yield attributes, which contribute significantly to seed yield and economic returns.

In contrast, delayed sowing generally exposes the crop to terminal heat stress, reduced moisture availability, or suboptimal thermal regimes, adversely affecting growth and yield parameters.Nutrient uptake efficiency and post-harvest soil nutrient status are also favourably influenced by timely sowing, enhancing both crop and soil health.The integration of weather-based planning and varietal suitability with optimal sowing time can serve as a climate-smart strategy to boost pulse production sustainably across different agro-ecological zones.

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Table 1: Comprehensive summary on effect of sowing time on agronomic and economic traits of major pulse crops

Trait	Crop	Sowing Time	Soil Type	Location	Research Findings	Reference
Plant height	Cowpea	15April vs 30 April&15May	Sandy loam	Mardin, Turkey	Significantly taller plants with 15 April sowing window	Togay *et al*. (2014) [61]
	Mungbean	20 April & 5 May	Sandy clay loam	Jammu, Chatha	Higher plant height at 60 DAS on both sowing dates	Palsaniya *et al*. (2017) [41]
	Greengram (Semi-rabi)	3 rd week of September	Sandy loam	Anand Agricultural University, Gujarat	Recorded significantly higher plant height	Gurjar *et al*. (2018) [19]
	Greengram	3 rd week of June & 1st week of July	-	ARS, Madhira, Telangana	Tallest plant stature recorded	Rao *et al*. (2018) [47]
	Greengram	1 st fortnight of July	Sandy loam	Prayagraj, U.P.	Maximum plant height recorded	Charan *et al*. (2024) [9]
Leaf Area Index	Mungbean	5 th April	Jharnapani, India	Sandy loam	Higher LAI than 15th April	Kumar and Kumawat, 2014 [26]
	Mungbean	16 th July	Ludhiana, Punjab	Loamy sand	Significantly higher LAI	Gill *et al*. (2018) [16]
	Greengram	1 st September	Assam, India	Clay loam	Highest LAI among sowing dates	Ahmed *et al*. (2023) [1]
	Greengram	20 th March	Jorhat, Assam	—	Higher LAI in summer sowing	Neog *et al*. (2025) [38]
Dry Matter Production	Chickpea	1 st FN of November	Black soils	IISS, Bhopal	Higher dry matter production than 2 nd FN Nov	Neenu *et al*. (2017) [37]
	Greengram	23 rd June	–	Parbhani, Maharashtra	Higher dry matter plant^{-1} than 30 June	Bobade *et al*. (2018) [8]
	Mungbean	16 th July	Loamy sand	PAU, Ludhiana	Significantly higher dry matter production	Gill *et al*. (2018) [16]
	Greengram	3 rd week June–1 st week July	–	Madhira, Telangana	Higher dry matter production	Rao *et al*. (2018) [47]
	Chickpea	1 st FN of October	Black soils	Karnataka	Higher dry matter accumulation	Niveditha *et al*. (2024) [40]
	Mungbean	16 July	Loamy sand	Ludhiana, Punjab	Higher dry matter accumulation	Gill *et al*. (2018) [16]
	Greengram	3 rd week June and 1 st week July	Not specified	ARS, Madhira, Telangana	Higher dry matter production	Rao *et al*. (2018) [47]
	Chickpea	1st fortnight of October	Black soils	Karnataka, India	Higher dry matter accumulation	Niveditha *et al*., 2024 [40]
Number of Branches Plant $^{-1}$	Mungbean	15 April	Clay loam	Dhaka, Bangladesh	Maximum branches recorded compared to 15 March and 15 May sowing	Jahan and Adam (2012) [21]
	Mungbean	30 July	Loamy sand	Ludhiana, Punjab	Higher number of branches during kharif season	Singh *et al*. (2018) [12]
	Mungbean	15 March	Clay	Imphal, CAU	Higher branches recorded during summer	Pamei *et al*. (2020) [42]
	Mungbean	15 Feb–4 April	Loamy	Jaguli, West Bengal	Branches increased with delayed sowing	Kundu *et al*. (2021) [31]
	Mungbean	26 March	Silty loam	Birbhum, West Bengal	Higher branches recorded compared to 16 March	Gorai and Mondal (2023) [17]
Days to 50% Flowering	Urdbean	5 August	Loamy sand	Ludhiana, Punjab	Reached flowering earlier than 5 July sowing	Singh *et al*. (2012) [23]
	Mungbean	1 st FN of June	Clay	Dharwad, Karnataka	Took more days for 50% flowering	Madhu *et al*. (2014) [32]
	Greengram	30 June	—	Parbhani, Maharashtra	Highest days to 50% flowering	Bankar *et al*. (2020) [5]
	Blackgram	1 st week March	Clay loam	Nadia, West Bengal	More days to flowering compared to late sowing	Benerjee *et al*. (2021) [6]
Number of Nodules Plant $^{-1}$	Greengram	25 June	Sandy loam	Modipuram, Meerut	Highest number of nodules	Singh *et al*. (2013) [53]
	Mungbean	26 March	Sandy loam	Jhansi, U.P.	Maximum nodules during summer	Kumar *et al*. (2016) [25]
	Greengram	15 March	Clay	Imphal, CAU	Higher nodules recorded	Pamei *et al*. (2020) [42]
	Mungbean	1 st fortnight July	Sandy loam	Prayagraj, U.P.	Significantly higher nodules at 60 DAS	Charan *et al*. (2024) [9]
Pods plant $^{-1}$	Mungbean	12 March	Silty clay loam	Uttarakhand	Higher pods plant $^{-1}$ compared to 20 February sowing.	Kumar *et al*. (2012) [23]
	Chickpea	1 December	—	Hisar, Haryana	Significantly maximum pods plant $^{-1}$ compared to 10 and 20 December.	Prasad *et al*. (2012) [43]
	Mungbean	2 nd fortnight of June	Sandy loam	Hisar, India	Early sowing produced significantly higher pods plant $^{-1}$.	Dhaka *et al*. (2018) [12]
	Greengram	1 April	Sandy loam	Talwandi, Punjab	Higher pods plant $^{-1}$ compared to other sowing dates.	Singh *et al*. (2019) [56]

	Greengram	16 June	—	Parbhani, Maharashtra	Maximum number of pods plant $^{-1}$ recorded when crop sown on 16 June.	Bankar *et al*. (2020) [5]
Seeds pod $^{-1}$	Mungbean	25 March	Sandy loam	Bihar, India	Significantly higher number of seeds pod $^{-1}$ recorded when sown on 25 March.	Kumar *et al*. (2010) [28]
	Mungbean	25 June	—	Badnapur, Maharashtra	Significantly higher number of seeds pod-1 over other sowing dates.	Mule *et al*. (2020) [35]
	Greengram	19 February	Sandy loam	Bhubaneswar, Odisha	Higher number of seeds pod-1 recorded when sown on 19 February.	Ranjan *et al*. (2020) [45]
	Mungbean	22 March	—	Kalyani, West Bengal	Maximum number of seeds pod $^{-1}$ observed when sown on 22 March compared to 3 March.	Bag *et al*. (2020) [4]
	Greengram	Last week of September	—	Kovilpatti, Tamil Nadu	Significantly higher number of seeds pod $^{-1}$ when sown during last week of September.	Subbulakshmi (2021) [57]
Pod weight	Horsegram	14 Sept	Sandy clay	Chhattisgarh	Higher pod weight in 14 Sept sowing	Sahu *et al*. (2007) [51]
	Chickpea	17–23 Sept	Black soil	Solapur, Maharashtra	Maximum pod weight recorded	Rathod *et al*. (2024) [48]
	Pigeonpea	15–30 May	—	GKVK, Bengaluru	Higher pod weight in early sowing	Thimmegowda *et al*. (2024) [58]
	Mungbean	15–21 Jan	Sandy clay loam	Kolhapur, Maharashtra	Superior pod weight in 3 rd MW sowing	Jadhav *et al*. (2025) [20]
Pod length	Mungbean	25 March	Sandy loam	Bihar, India	Higher pod length recorded when sown on 25 March during summer season.	Kumar *et al*. (2010) [28]
	Mungbean	15 April	—	Dhaka, Bangladesh	Significantly higher pod length compared to other sowing dates.	Jahan and Adam (2012) [21]
	Blackgram	10 July	—	—	Maximum pod length recorded compared to rest of the sowing dates.	Gadpale (2013) [13]
	Urdbean	Up to 20 March	—	Pantnagar, Uttarakhand	Pod length increased with delayed planting up to 20 March.	Gangwar *et al*. (2013) [14]
	Mungbean	30 March	—	Chitwan, Nepal	Significantly longer pods recorded when sown on 30 March.	Neupane *et al*. (2023) [39]
Thousand Seed weight	Mungbean	30 March	—	Peshawar	Maximum test weight recorded with 30 March sowing.	Rehman *et al*. (2009) [50]
	Greengram	15 March, 25 March	—	Banswara, Rajasthan	Maximum seed index at 15 March, at par with 25 March.	Meena *et al*. (2017) [33]
	Mungbean	2 nd FN June	Sandy loam	Hisar, India	Higher thousand seed weight in early sowing (2 nd FN June).	Dhaka *et al*. (2018) [12]
	Mungbean	25 June	—	Badnapur	Significantly higher thousand seed weight with 25 June sowing.	Mule *et al*. (2020) [35]
	Mungbean	15 March	Clay soils	Imphal	Higher thousand seed weight with 15 March sowing.	Pamei *et al*. (2020) [42]
Seed yield	Greengram	30 March	Sandy loam	Faizabad, Uttar Pradesh	Significantly higher seed yield during summer season	Ram and Dixit (2001) [44]
	Greengram (semi rabi)	3rd week of September	Sandy loam	AAU, Gujarat	Higher grain yield	Gurjar *et al*. (2018) [19]
	Greengram	25 August	—	AAU, Jorhat	Higher seed yield	Annie *et al*. (2020) [2]
	Greengram	1 March	Loamy sand	West Bengal	Highest seed yield	Ghosh *et al*. (2020) [15]
	Greengram	1 March	Loamy	West Bengal	Highest grain yield and is was at par with 15 Feb	Kumar and Rajput (2020) [29]
	Mungbean	15 July	—	Ludhiana, Punjab	Higher seed yield followed by 1 and 30 July	Sandhu and Singh (2020) [2]
Haulm yield	Chickpea	10 November	Sandy clay loam	Varanasi, Uttar Pradesh	Early sowing produced maximum haulm yield	Tiwari and Meena (2014) [60]
	Greengram	23 June	—	Parbhani, Maharashtra	Significantly higher haulm yield compared to later	Bobade *et al*. (2018) [8]

					sowings	
	Greengram	3 rd week of September	Sandy loam	Anand, Gujarat	Significantly higher haulm yield	Gurjar *et al*. (2018) [19]
	Greengram	15 July	Sandy loam	Shivamogga, Karnataka	Significantly higher haulm yield	Ashwini *et al*. (2021) [3]
	Urdbean	27 June	—	Chhattisgarh, India	Highest straw yield with timely sowing	Gupta *et al*. (2024) [18]
Protein content	Cluster bean	Different dates	Clay soils	Navsari, Gujarat	No significant effect of sowing time on protein content	Vishal and Swapnil (2015) [63]
	Greengram	12 Feb and 5 March	—	Bhubaneswar, Odisha	Highest protein content in 12 Feb sowing; at par with 5 March	Biswas *et al*. (2024) [7]
	Pigeonpea	1 st FNof May	Red sandy loam	GKVK, Bengaluru	Highest protein content recorded	Dash *et al*. (2024) [10]
GDD	Chickpea	45 th Standard Week	Black soils	Dharwad, Karnataka	Higher GDD for 50% flowering compared to other sowings	Kiran and Chimmad, (2018) [22]
	Mungbean	20 July	—	—	Reduction in GDD accumulation to reach maturity	Ransing *et al*. (2014) [46]
	Greengram	16 June	—	Parbhani,Maharashtra	Higher GDD for all phenophases	Bankar *et al*. (2020) [5]
	Mungbean	1 July	—	Ludhiana, Punjab	Maximum GDD at all stages *vs* late sowing (30 July)	Sandhu and Singh (2020) [2]
PTU	Urdbean	5 July	Loamy sand	Ludhiana, Punjab	Higher PTU accumulation *vs* 5 August sowing	Singh *et al*. (2012) [23]
	Greengram	16 June	—	Parbhani, Maharashtra	Higher PTU for all phenophases	Bankar *et al*. (2020) [5]
	Greengram	2 nd FN June	—	Hisar, India	Maximum PTU at physiological maturity	Kumari (2023) [30]
HTU	Mungbean	2 nd FN June	Sandy loam	Hisar, India	Higher HTU accumulation up to maturity	Dhaka *et al*. (2018) [12]
	Chickpea	15 Nov (Early)	Clay soils	Akola, India	Highest HTU; early sowing required more HTU than normal & late	Thombre *et al*. (2019) [59]
	Greengram	25 Aug – 25 Sept	Sandy loam	Jorhat, Assam	Decrease in HTU accumulation with delayed sowing	Annie *et al*. (2020) [2]
Nutrient uptake	Mungbean	25 June	Sandy loam	Meerut, Uttar Pradesh	Significantly higher N, P, K uptake vs other sowing dates	Singh *et al*. (2013) [53]
	Mungbean	Various sowing dates	Sandy clay loam	Jammu & Kashmir	No significant difference in N, P, K uptake among sowing dates	Palsaniya *et al*. (2017) [41]
	Pigeonpea	II fortnight of September	Sandy clay loam	Tirupati, Andhra Pradesh	Higher N, P, K uptake during rabi season	Nagamani *et al*. (2020) [36]
	Fodder cowpea	1 st fortnight of January	Sandy loam	Tirupati, Andhra Pradesh	Higher nutrient (N, P, K) uptake at harvest	Mobeena *et al*. (2022) [34]
Post harvest soil nutrient status	Mungbean	Different sowing times	Sandy loam	Jharnapani, Nagaland	No significant effect on soil N, P, K	Kumar *et al*. (2015) [27]
	Fodder cowpea	1st FN February and 2 nd FN January	Sandy loam	S.V. Agricultural College, Tirupati, Andhra Pradesh	Higher available N, P, K in both early sowings	Mobeena *et al*. (2022) [34]
Economics	Mungbean	5 April	Sandy loam	IARI, Delhi	Maximum gross return, net return and B:C ratio Higher B:C ratio	Kumar *et al*. (2015) [27]
	Mungbean	1 st FN October	Sandy loam	Mahanandi	Maximum gross return, net returns and B:C ratio	Reddemma (2018) [49]
	Blackgram	15 November	Clay soils	Akola	Higher gross & net returns and B:C ratio	Thombre *et al*. (2019) [59]
	Chickpea	1 st week of July	—	Satna, MP	Higher gross, net returns and B:C ratio than later sowings	Vaishya and Lilhare (2022) [62]
	Greengram	26 th and 27 th MW	Clay soils	Nagpur	Higher net returns and B:C ratio	Deshmukh *et al*. (2024) [11]

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