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REVIEW PAPER

A review on the growth, yield and oil contents of *Brassica* under rainfed conditions

Khalid Mehmood[1]*, Saima Nasreen[1], Abdul Latif[2] and Adnan Noor Shah[3]

[1]Department of Biology, Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan
[2]Barani Agricultural Research Institute, Chakwal, Pakistan
[3]Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan, Pakistan

*****Corresponding author's email: khalidmehmood@uaar.edu.pk

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Abstract

Brassica species have been considered an important source of oil in worldwide. These are being cultivated either as a vegetable, fodder or oil purpose. Their oil can be used for cooking and in different industries depending on their oil contents. The oil containing high quantity of monounsaturated fatty acids (oleic acid and linolenic acid) is highly suitable for cooking. Phytochemicals present in *Brassica* reduces the oxidative stress and prevent cancer in human. The growth and yield of *Brassica* species in rainfed areas depends on rainfall. Rainfed agriculture is most commonly practiced by poor community of many countries including Pakistan. The problems with rainfed areas are irregularity in rainfall, results in waterlogging due to heavy rainfall or drought stress due to low rainfall. The other problems are soil erosion, nutrient deficiency, weed infestation and crusting that limit the growth and yield of crops of these lands. *Brassica* species are highly susceptible to drought stress from flowering to seed producing stage, their oil contents reduced due to water stress. This review article highlights the growth, oil content and yield of various *Brassica* species under rainfed conditions. It also highlights the *Brassica* species that performs best in terms of growth, oil content and yield in rainfed conditions. Many numbers of studies reported that *Brassica* has high growth rate, fresh and dry biomass, if rainfall is just before or after the flowering stage. Oil contents reduce when precipitation rate is low, but some varieties have been reported having high growth rate, oil content and biological yield in rainfed condition. These varieties should be recommended to farmers for cultivation in rainfed areas.

Keywords: *Brassica*, Growth, Oil contents, Rainfed, Yield

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Introduction

The growth and yield of crops in rainfed conditions depends on rainfall instead of irrigation. The agriculture sector of rainfed areas is prone to various kinds of biotic and abiotic factors (i.e., crusting, erosion, drought stress, nutrient deficiency and weed infestation) that limit the growth and yield potential of crops. Beside these problems, still this sector is providing ample food and good source of income for poor communities. Distribution of rainfed areas in worldwide is 95%, 90%, 60%, 65% and 75% of total farmed area of Sub Saharan Africa, South Asia, Latin America, East and North America, respectively (Wani et al., 2009). In Pakistan, about 80% area falls under arid and semi-arid region. Annually half of the country gets less than 250mm of rainfall so climatically it is categorized as desert or nearly desert and 25% of the total cultivated area lies in dry land agriculture or rainfed (barani) agriculture (Farooq et al., 2007). Rainfed areas of Pakistan comprising northern mountains, Pothwar Plateau, and north-eastern plains that receives less than 500 mm/ annual rainfall. However about 75% of these areas receives less than 250 mm/ annual rainfall (Baig et al., 2013).

Various species of *Brassica* have diverse potential of growth, yield and oil contents in rainfed conditions. These can be used as vegetable oil or fodder for animals, but three species (*Brassica rapa*, *Brassica napus* and *Brassica oleracea)* are being cultivated as a fodder, vegetable and oil purpose (Jan et al., 2017) (Fig. 1). The genus *Brassica* ranked the 2nd largest oil seed crops after soybean (*Glycine max*) worldwide and accounts for 14% of total oil production (Mc Vetty & Duncan, 2015). Out of 37 species of *Brassica* genus, four species (*Brassica rapa* (turnip mustard), *Brassica napus* (rapeseed), *Brassica juncea* (brown mustard), and *Brassica carinata*) are being cultivated for oil production (Gupta, 2016; Jan et al., 2016; Yousaf et al., 2018). Oil contents in different *Brassica* species fluctuates such as 21%, 28%, 31% and 46% in *Brassica nigra*, *B. oleracea*, *B. rapa* and *B. napus*, respectively. In all the species, 89 to 94% of total fatty acids are oleic acid, linolenic acid, erucic acid, stearic acid and palmitic acid (Sharafi et al., 2015). Some *Brassica* species contains high quantity of erucic acid and are very low in linoleic and oleic acid due to which their oil cannot be fit for human consumption instead is of industrial grade (Cartea et al., 2019). Phytochemicals in *Brassica* species prevent oxidative stress by inducing antioxidant enzymes, stimulate immune system, and prevent carcinogenic mutation as well as malignant formation (Herr & Büchler, 2010).

Brassica crop grows well under low temperature (give low temp range) until flowering but after flowering it can tolerate high temperature (up to which temp, give figure). In addition to high temperature, drought stress results in reduction of seed size, yield and oil contents (Jan et al., 2008). A negative impact was observed on canola production due to fluctuations in temperature and rainfall (Khan et al., 2014). It is extremely vulnerable to water stress and its production declined to a significant level at flowering and seed setting stage (Din et al., 2011). According to Garlinge (2005), highest yield and oil content were obtained in area with high to medium rainfall after flowering. It was observed that a low temperature and adequate rainfall is required for better crop production. But very high amount of rainfall can cause waterlogging conditions leading to reduction of yield up to 50% (Potter et al., 1999).

Rianfed agriculture is facing diverse problems such as drought stress, nutrient deficiency, soil erosion, crusting and weed infestations that limit the yield potential of crops of these lands (Baig et al., 2013). Keeping in view the vulnerability of rainfed areas and the importance of *Brassica* this review article gathers, summarizes the impact of such condition on growth, yield and quality of Brassica either grown for vegetable, fodder or oil purpose. Moreover, the article also exhibits the best performing cultivars for their potential usage.

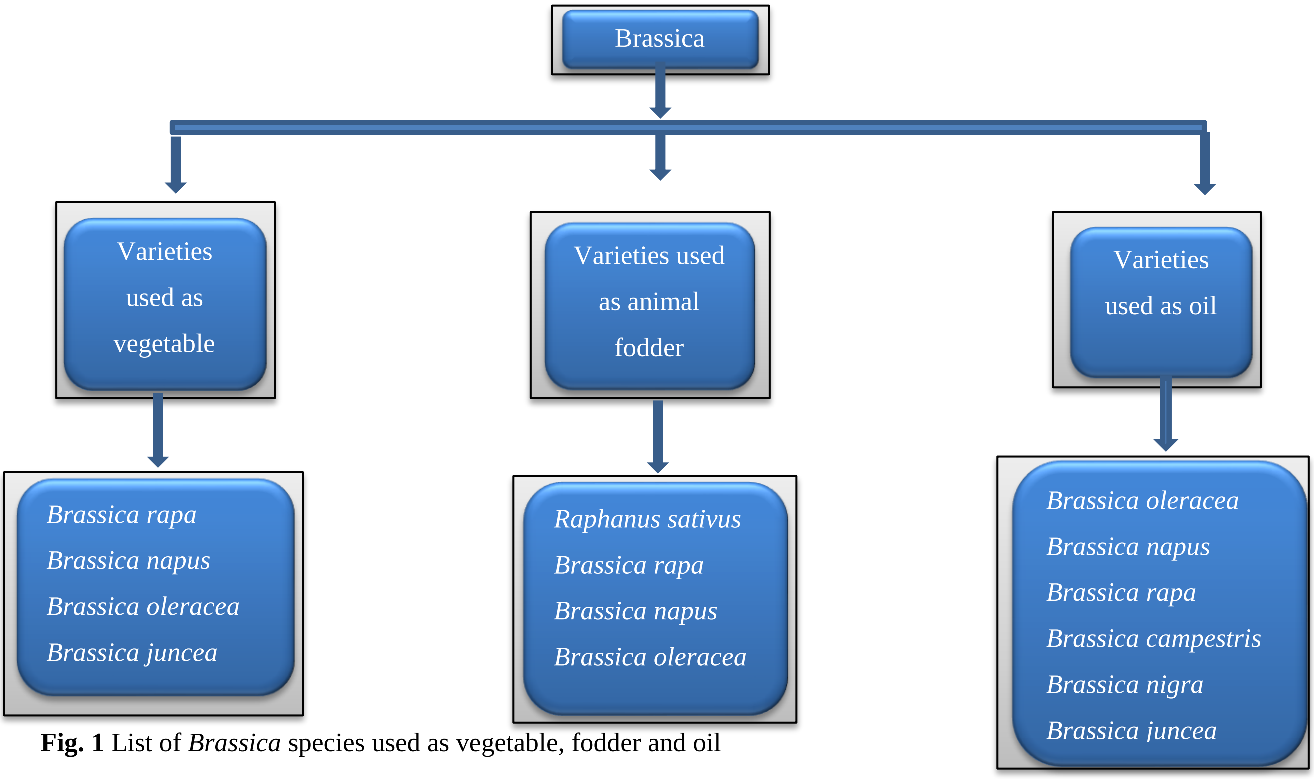

Fig. 1 List of *Brassica* species used as vegetable, fodder and oil

Rainfed areas on world map

Worldwide, about 80% agricultural area is under rainfed conditions with low yield and high-water loss. As compared to irrigated agriculture that is recent practice, rainfed agriculture is almost 10000 years old (Biradar et al., 2009). According to worldwide rainfall distribution, there is general trend of wet areas near equator and dry areas near tropics of Cancer and Capricorn. There is almost zero precipitation at Sahara Desert, Gobi Desert and major areas of Australia. From north to south there is decrease in rate of precipitation and increase from east to west. In Southeast Asia, rainfall is high at western coasts of India, Thailand and some regions of Himalaya. However, less than 100 mm y^{-1} rainfall has been observed in north of Himalaya, Pakistan and western part of India (Droogers et al., 2001) (Fig. 2).

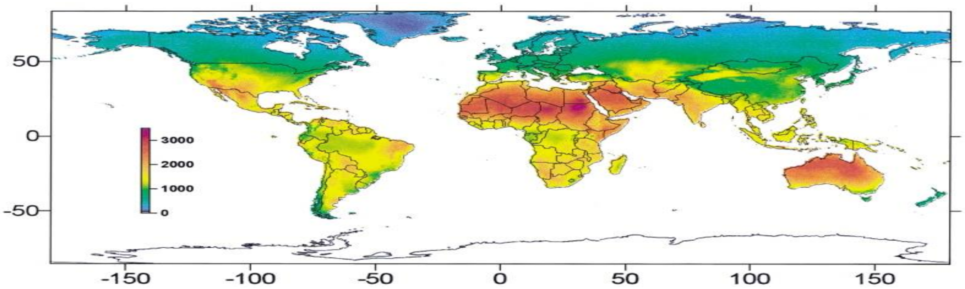

Fig. 2 Global map showing annual rainfall pattern in continents (Droogers & Allen, 2002)

Globally, 46% area on earth is not suitable for rainfed agriculture due to worse climatic condition but 7 billion hectares have good potential for growth of rainfed crops. Out of these 7 billion hectares, about 4.7 billion hectares are classified as highly or very highly suitable area for rain-fed agriculture. According to World Resource Institute only 1.5 billion hectares are used for agricultural purpose while remaining area is present in form of forests, grasslands and wetlands (Salmon et al., 2015).

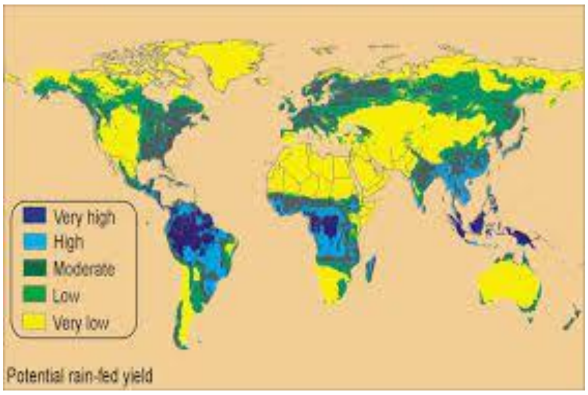

Fig. 3 Potential of rainfed on global scale (Droogers et al., 2001)

According to this global map, potential of rainfed agriculture is almost zero in Namibia, Botswana and substantial part of South Africa. It is also impossible in most areas of India and Pakistan but moderate to low in some other areas of these countries. Rainfed agriculture potential is very high in Burma, Bangladesh and Eastern India (Droogers et al., 2001) (Fig. 3).

Impact of rainfed condition on growth of *Brassica*

Various *Brassica* species having high growth rate under rainfed conditions are listed in Table 1. Several growth stages of brassica are sensitive to climatic conditions such as high temperature and dry weather leading to decreased germination and early development of plants (Lardon & Triboi-Blondel, 1995). *Brassica* has immense importance as a fodder for livestock in rainfed areas because they are available in December and January when other forage sources are not available. A comparison was made between different *Brassica* varieties under rainfed condition for their growth as forage production. Results indicated that Hyola-401 produced maximum fresh and dry biomass followed by Omega-1 and Omega-3 (Ansar et al., 2014). High dry mass production was observed before flowering under rainfed conditions as compared to irrigated conditions. Similarly, after flowering, leaf area index was rapidly declined under non irrigated conditions (Clarke & Simpson, 1978).

Abiotic stress such as drought is major problem for rained agriculture especially for brassica species. So, moisture conservation techniques including mulching and anti-transpirant are being used along with intercropping. Intercropping with chickpea provide better land cover, conserve soil moisture and resist water lodging in case of heavy rainfall (Singh & Rana, 2006). Drought stress affects the size and growth of leaves. The size of leaves directly linked with use of light energy, rate of photosynthesis and the other physiological process like photorespiration, temperature regulation and transpiration. Which are ultimately linked with the growth of brassica (Zhu et al., 2010).

Irregular rainfall in semi-arid regions is another problem for *Brassica* species but Zhao et al. (2016) reported a tolerant variety of *Brassica* (*Brassica carinata)* that can withstand many abiotic stresses including low precipitation. Various canola genotypes viz. Zafar-2000, Bulbul-98, Abaseen, Shiralee, Rainbow, Dunkeld, 19-H Con-I, Con-II and Westar were compared for their performance in different agro-ecological regions. It was observed that the crop growth rate was highest in areas having high precipitations beside chlorophyll contents, seed yield, oil yield and protein contents. Further they also indicated that among the above canola varieties, Zafar 2000 had the highest growth rate, chlorophyll content index, seed /oil yield and net assimilation rate, but in second year, all the former parameters were noted higher in 19-H (Sher et al., 2017).

Impact of rainfed condition on *Brassica* Yield

High rainfall in pre-flowering phase increases yield but in post-flowering phase high precipitation is required to get excessive yield (Lardon & Triboi-Blondel, 1995). In order to improve yield, it is necessary to assess the contribution of each trait towards the yield (Tuncturk & Ciftci, 2007) *Brassica* species having high biological yield under rainfed conditions have been enlisted in Table 1.

In order to evaluate yield performance of different brassica species, 10 genotypes were grown in irrigated and rainfed conditions. There were two irrigation modules; one was only irrigated before sowing that depicts rainfed or moisture stress and other was with normal irrigation. Results have shown that photosynthetic pigments (carotenoids, total chlorophyll, Chlorophyll a and chlorophyll b) were declined to significant amount under rainfed conditions. Decrease in relative water content was observed but comparatively water saturation deficit and relative saturation deficit increased under rainfed conditions. Proline content, sugar content, malondialdehyde content and antioxidant enzymes were observed to be increased in stress conditions. However, oil content, seed and biological yield had been decreased in all of the genotypes (Sodani et al., 2017). A local variety (HS-98) of *Brassica napus* was compared with the commercial varieties (Rainbow, Dunkled, Altex and Oscar) regarding their yield. The agronomic traits (siliqua length, siliqua per plant, width, 1000 seed weight and pedicle length) were taken into consideration. The seed quality parameters included; linolenic acid, oleic acid, seed moisture, percentage of oil and protein were also considered. HS-98 showed maximum siliqua length per plant (6.7 cm) and number of siliqua per plant (156) therefore it was high yielding variety among all the varieties. The seed protein (25.1%) was highest in HS-98 followed by Rainbow, Oscar, Altex and Dunkled (Ahmad et al., 2008).

Winter oilseed rape production was also affected by low nitrogen beside the weather conditions. In this regard, a study was designed to evaluate various sources for the oil contents and yield of 4 rapeseed cultivars under the effect of five nitrogen dosages during four growing seasons by applying three sowing dates. Six climatic factors were observed at different growing stages from germination to ripening. It was noted that water was the major factor that contribute the seed yield and oil content go together with cooler temperature during the seed development (Takashima et al., 2013). Cultivation time and temperature effects the yield and oil contents of brassica species. It was observed that late sowing results affects the oil and yield content of brassica while high temperature at the time of seed filling leads to decreased seed, oil content and total protein (Ziadoon & Mouhamad, 2019). In another experiment, four brassica cultivars (Sultan raya, Brad-1, Dunkled and cont-II) were evaluated under agro-ecological conditions of Quetta (rainfed conditions) in order to evaluate their yield performance. Results have shown that Dunkled performed best in term of yield parameters followed by cont-II (Khan et al., 2019).

Drought stress reduced the yield components of brassica. A study was conducted to induce drought stress on four spring genotypes of two oilseed rape species (*Brassica napus* and *Brassica campestris*) at different times. Results have shown that yield was lowest in both species under drought stress. The stem length was also reduced. *B. napus* perform better in term of grain yield after irrigation as compared to *B. campestris*. In *Brassica. campestris*, Span genotype was sensitive when water stress was first time induced at the stage of stem elongation, while other genotypes were sensitive at the later reproductive stages. Harvest index and seed weight per pod were the important characters that contribute to yield in both species (Deligios et al., 2013). In another experiment different canola cultivars (Shirale, Con-II, Oscar, 19H and Rainbow) were studied by conducting pot experiment and drought stress was applied after applying drought stress at different growth stages. Drought stress was executed at flowering and pod filling growth stage. Data of various physiological attributes such as proline and protein contents, leaf chlorophyll a & b, and agronomic attributes such as number of seeds/pods, pods/plant, grain yield/plant) were recorded. It was observed that their yield was significantly reduced due to drought treatment. Grain yield was reduced when stress was applied at flowering stage. Average yield was found high in Rainbow and less in Oscar (Din et al., 2011).

Seven *Brassica* genotypes (Hyola-401, BARD-1, Raya Anmol, CON II, Sarhein - 95, 19 -H and Canola Raya) were compared for yield under different agro-climatic conditions. Between all the seven examined varieties of *Brassica* the CON II and BARD–1 gave highest seed yield (898 kg ha^{-1}) and (889.33 kg ha^{-1}) respectively as compared to other varieties. These genotypes of *Brassica* attained higher yields with excellent quality of seed under agro climatic condition of Quetta (Ahmed et al., 2016). Zafar-2000, BSA, Pakola, Con.1, Con.2, Rainbow, Abaseen, Bard-1, SPS-5 and KJ-119 varieties of *Brassica* were tested for their growth and yield under rainfed conditions. Results have shown that Abaseen and KJ-119 have maximum yield as compared to other varieties in term of maximum pods per plant and maximum seeds per pod (Hassan et al., 2014). Eight cultivars of canola crop Shiralee, Bulbul-98, Dunkled, Cyclone, Ac-Excel, DGL, Rainbow and 'Faisal Canola' were evaluated for computing some productivity and physiological indices in normal growing conditions. According to results, Rainbow and Bulbal-98 produced maximum seed yield and biological yield respectively (Noreen et al., 2016).

Impact of rainfed condition on *Brassica* oil contents

Water stress and late sowing have negative impact on oil production, seed oil content, oil yield and oleic acid contents of different spring rapeseed (Rad et al., 2014). The water holding capacity of soil and amount of precipitation are important factors in oil content of *Brassica* species. High rainfall during flowering period, increases the canola seed set and oil contents. Increased dry mass production, seed quality and pod density were also observed if precipitation rate is high during and after flowering (Weymann et al., 2015) *Brassica* species having high oil contents under rainfed conditions are enlisted in Table 1. Five genotypes of rapeseed were tested for parameters with respect to agronomy, yield, quantity and quality of oil. Regarding high yield contribution characteristics, such as pods per plant, inflorescence length, and genotype alarms perform well with respect to all others. The same variety showed low levels of erucic acid (23.67 µmol/g), glucosinolate (44.82 µmol/g) and significantly high levels of oleic acid (59.01%). Therefore, the variety Siren was recommended for cultivation in rainfed areas for the reason that of its superior oil quality and greater yield. It was also suggested to include this variety in the breeding programs for *Brassica napus* (Rahman et al., 2009).

An experiment was performed to evaluate oil yield stability and seed in NS rapeseed genotypes in unpredictable environmental situations of northern Serbia. In this experiment 40 winters and 9 spring genotypes were grown. Results revealed that the oil and seed yield was significantly influenced by Genotype and environment (year). Winter genotypes NS-L-102 and Nena were the most tolerant and high yielding while hybrid genotype NS-H-R-3 was pointed out for oil yield. These cultivars were suggested for carrying out in future breeding programs (Marjanović et al., 2011). The oil contents of *B. rapa* and *B. juncea* were evaluated by conducting an experiment and it was noted that higher oil contents were recorded in *B. rapa* than in *B. juncea*. Their oil contents contained high erucic acid and good oxidation stability (Pavlista et al., 2011). Five rapeseed genotypes were evaluated for yield, oil content and quality. Out of them Siren genotype was best in term of yield potential then followed by MRS-1. This genotype was also good in term of plant height and pods per plant. Low level of glucosinolate, erucic acid and higher amount of oleic acid were observed in this genotype (Rahman et al., 2009).

A field experiment was conducted by using 25 winter rapeseed cultivars to find out the correlation between certain characteristics and to study the direct and indirect effects of these characteristics on oil production. Correlation results showed a positive correlation between number of pods on the main stem and branches per plant. Conversely, plant height was not correlated with 1000-

seed weight, yield of seedsand oil ratio. It was observed that yield directly affects the oil content on basis of comparing the effects of seeds and oil production on various yield components. similarly the indirect effects of all other characteristics are large with addition to oil ratio (Basalma. 2008). Five cultivars of *B. juncea* and *B. napus* were cultivated for checking out the correlation of yield, oil content and growth. There were significant variations among the performance of these cultivars. According to results *B. napus* show maturity in early stages and have high oil contents, while *B. juncea* has high yield and greater no. of pods per plant (Hossain et al., 2019).

An experiment was conducted to investigate the effect of water stress on oil in different rapeseed cultivars. The factors such as irrigation regimes (control, irrigation interrupted from siliqua formation stage, flowering stage and seed filling stage) in main plots. The cultivars (Zarfam, Licord and Okapi) in subplots were studied. The results of this experiment indicated that rapeseed cultivars significantly affected with respect to oil, grain yield, siliqua number per plant, thousand grain weight and grain number per siliqua, whereas water stress had significant effect on 1000 grain weight and grain number per siliqua ($P = 0.01$) at ($P < 0.05$). The maximum thousand grain weight and highest oil yield was recorded in Okapi cultivar, Maximum siliqua number per plant and highest grain yield in Licord cultivar and highest grain number per siliqua in Zarfam cultivar were recorded in control irrigation. High drought tolerance index was showed by Licord cultivar. These findings also showed that drought stress reduced oil quantity of rapeseed (Moaveni et al., 2010).

Table 1 *Brassica* varieties performing best in term of high growth rate, yield and oil contents under rainfed condition

Best performing *Brassica* genotype	Scientific name of species	High yielding parameter	Country of cultivation	Reference
Hyola-401	*B. napus*	Higher fresh and dry biomass	Pakistan	(Ansar et al., 2014)
Zafar-2000 and 19-H	*B. napus*	Highest chlorophyll stability index and maximum seasonal crop growth rate	Pakistan	(Sher et al., 2017)
Varuna	*B. juncea*	Higher dry mass production and crop growth rate	Swedish	(Kjellström, 1993)
Siren	*B. napus*	Higher level of oleic acid	Pakistan	(Rahman et al. 2009)
Okapi	*B. napus*	High level of oil contents	Iran	(Moaveni et al., 2010)
Oscar	*B. napus*	Good in seed oil content, erucic acid and glucosinolates	Pakistan	(Cheema et al., 2001)
HS-98	*B. napus*	Higher siliqua per plant, siliqua length per plant and 1000 seeds weight	Pakistan	(Ahmed et al., 2008)
CON II and BARD–1	*B. napus*	Higher biological yield, plant height and weight per thousand seeds	Pakistan	(Ahmed et al., 2016)
KJ-119	*B. napus*	Maximum pod per plant and maximum seeds per pod	Pakistan	(Hassan et al., 2014)
Abaseen Rainbow	*B. juncea* *B. napus*	High yield	Pakistan	(Din et al., 2011)
Bulbal-98	*B. napus*	Maximum biological yield and seed yield	Pakistan	(Noreen et al., 2016)
Dunkled	*B. napus*	High yield component	Pakistan	(Khan et al., 2019)

Conclusion and future recommendations

Rainfed agriculture contributes a significant share to the economy of the any country. It is being practiced from very early time. The problems of these areas limit the growth and productivity of crops. From this review article, it has been concluded that under rainfed conditions growth rate, fresh & dry biomass, leaf area index, oil contents, seeds production and biological yield in *Brassica* species fluctuated with precipitation rate and water availability. Rainfall is highly recommended before and after the flowering stage as it results in maximum seed production and increased oil contents. *Brassica* species are sensitive to drought stress during flowering period as it negatively effects on growth rate and yield. But some of the *Brassica* varieties have been recommended for rainfed areas for cultivations after evaluation their performance under drought stress for checking their growth, oil contents and yield. By keeping in view, the increased demand of oil, vegetable and animal fodder of *Brassica* species. The drought tolerant varieties should be recommended to farmers of rainfed areas. The already evaluated drought tolerant varieties should be further improved through latest genetic engineering and tissue culturing techniques. The oil contents can be improved by incorporating genes and through breeding programs.

The problems of rainfed areas can be minimized by adopting water harvesting and water conservations techniques. Drip and Sprinkler irrigation should be in practice for conservation of water and improving productivity in terms of growth, yield and oil contents. Erosion results in nutrient deficiencies or nutrient imbalances in soil that results in low productivity of crop in rainfed conditions. Proper nutrient management is the requirement of these areas for improving the productivity potential of the crops including other crops. The use of bio-fertilizer can improve yield of legumes and economize the use of nitrogen fertilizer. Some management practices (such as proper sowing time, selection of appropriate variety, eradication of weeds, insect pest management) can improve the yield potential of crops in rainfed areas. Either the rainfed agriculture has diverse issues but applying proper management strategies along the scientific lines, we can get maximum growth yield and oil contents of brassica species as well as other crops under rainfed conditions.

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