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Assessing the Use of Butachlor 5G in High and Mid Altitude Rice Growing Areas in Bhutan: A Case Study

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ABSTRACT

Rice is a vital cereal crop in Bhutan, cultivated widely for domestic consumption. Rice production is gradually decreasing due to diverse reasons including labour shortages and insufficient irrigation water. With the shortage of farm labour, weed management is challenging and Bhutanese farmers have long relied on Butachlor 5G for weed control. However, prolonged use of a single herbicide can lead to herbicide resistance in weeds. This study aimed to determine the extent of use of the weedicide and to assess the development of Butachlor resistance in paddy weeds through farmers' perceptions. The study, conducted in four western rice-growing areas, surveyed 190 farmers using semi-structured questionnaires. The findings revealed that Butachlor has been extensively used for over three decades, with most farmers applying it more than the recommended dosage. Despite this, 86.85% of respondents reported a decrease in Butachlor's effectiveness over the years. More than half of the respondent (50.53%) believed that weeds had developed resistance to Butachlor, a concern that correlated with the increased dosage used. The findings suggest a diminishing efficacy of Butachlor, potentially attributed to the development of herbicide resistance. Of significance, the study identifies Potamogeton distinctus as the most prevalent weed, followed by Schoenoplectiella juncoides and Pontederia vaginalis in the surveyed areas.

Keywords: *Butachlor; Herbicide; Paddy; Resistance; Weed*

1 Introduction

Rice is the important cereal crop in Bhutan and it is largely cultivated for domestic consumption. Rice is grown in all agro-ecological zones of Bhutan, across all 20 Dzongkhags, except the alpine zone in the north. In 2021, the area under rice production was 24055 acres with a total production of 40508 MT (NSB, 2021). However, the production of paddy is observed to decrease gradually due to urbanization and rapid socio-economic development.

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The major challenges faced by rice producers are labour shortage, lack of irrigation and weed management. Weed management has emerged as a significant challenge in rice production in Bhutan due to labour shortage and limited irrigation availability.

Weeds are identified as a major biological constraint that hinders attainment of optimal rice productivity in major rice producing countries of South Asia (Rao & Matsumoto, 2017). In Bhutan, rice yield losses of up to 50% due to weeds have been reported from lowland rice production (Karma & Ghimiray, 2006). The Royal Government of Bhutan introduced the weedicide Butachlor in granular formulation in the 1980s to manage grass and sedge weeds in paddy fields. Over the past 2-3 decades, Butachlor 5% GR has been the primary herbicide solution adopted by paddy growers across various regions of Bhutan. Despite a decline in the overall cultivated area, there has been a noticeable and consistent increase in the demand for Butachlor. This trend underscores the herbicide's effectiveness in weed management and its widespread acceptance among farmers.

However, as the reliance on a single herbicide continues, it is essential to monitor and assess the long-term implications on soil health, potential herbicide resistance in weed populations, and environmental sustainability. Diversification of weed management strategies and continued research into alternative, sustainable practices are imperative for maintaining the effectiveness of weed control measures and ensuring the sustainable paddy farming in the country.

The persistent use of a singular herbicides has been recognized as a potential catalyst for herbicide resistance in weeds (Cobb, 2022). In the context of Bhutan, Butachlor, classified as a pre-emergence selective herbicide within the Chloroacetanilide group, has been extensively employed to combat annual grasses and sedges in paddy fields. The targeted weeds include *Echinochloa spp*., *Paspalum distichum*, *Cynodon dactylon*, *Cyperus iria*, *Cyperus difformis*, *Schoenoplectiella juncoides*, and *Fimbristylis littoralis*.

Despite three-decade-long use of Butachlor for weed control in paddy, the development of resistance of weeds to this weedicide has not been studied. Recognizing this critical gap, this present study was undertaken to gather the perceptions of farmers and assess the emergence or absence of Butachlor resistance in the targeted paddy weed species. This study aimed to provide a comprehensive understanding of the on-the-ground experiences of farmers who have relied on Butachlor for weed management. Furthermore, the study aimed to provide valuable insights into the existing status of Butachlor resistance in paddy weeds, as well as to assess

whether farmers are adhering to the recommended usage guidelines for Butachlor that is crucial for devising sustainable weed management strategies.

2 Materials & Method

2.1 Study site

The study was conducted across four rice-growing areas in Punakha, Wangduephodrang, Paro, and Thimphu. Seventeen gewogs were selected for the study from four dzongkhags (Table 1).

Table 1. Gewogs selected for the study under each Dzongkhag

Dzongkhag	**Gewogs**
Wangdue Phodrang	Bjena, Gasetsogom, Gasetsowom, Kazhi, Nahi, Ngyisho, Rubesa, Thoedtsho
Punakha	Barp, Dzomi, Kabesa, Shelngana
Paro	Dopshari, Lamgong, Lungye, and Tsento
Thimphu	Maedwang

Butachlor has been widely used by paddy growers in these areas to control weeds in their paddy fields for over two decades (Figure 1), and its application and demand from the fields have been increasing over the years (Figure 2).

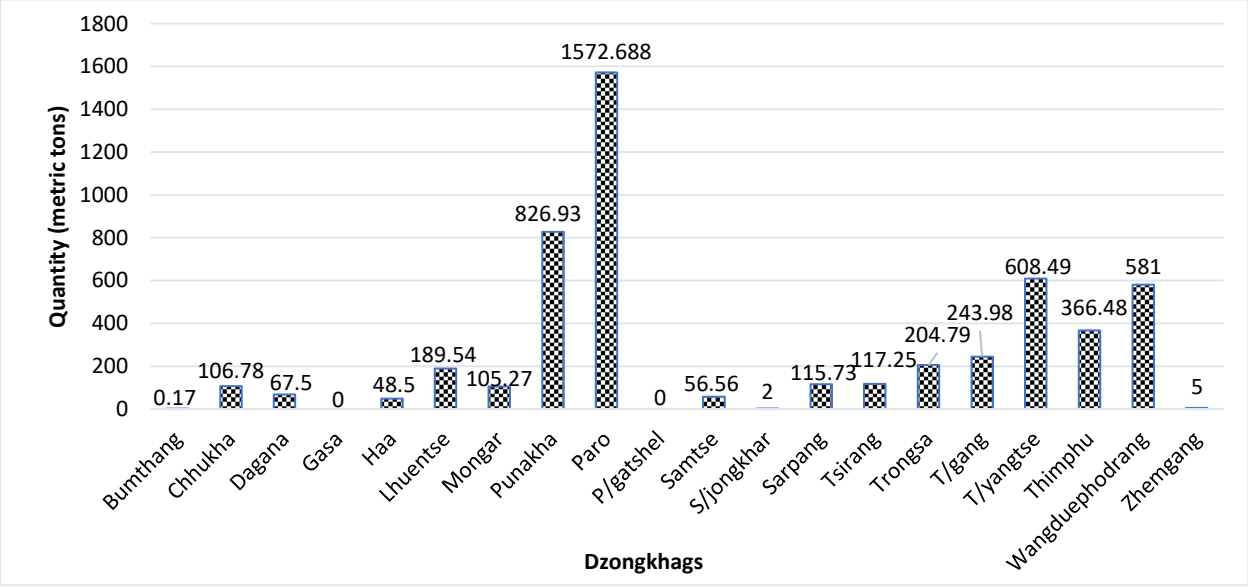

Figure 1. Dzongkhag wise butachlor 5% GR distribution in 13 years

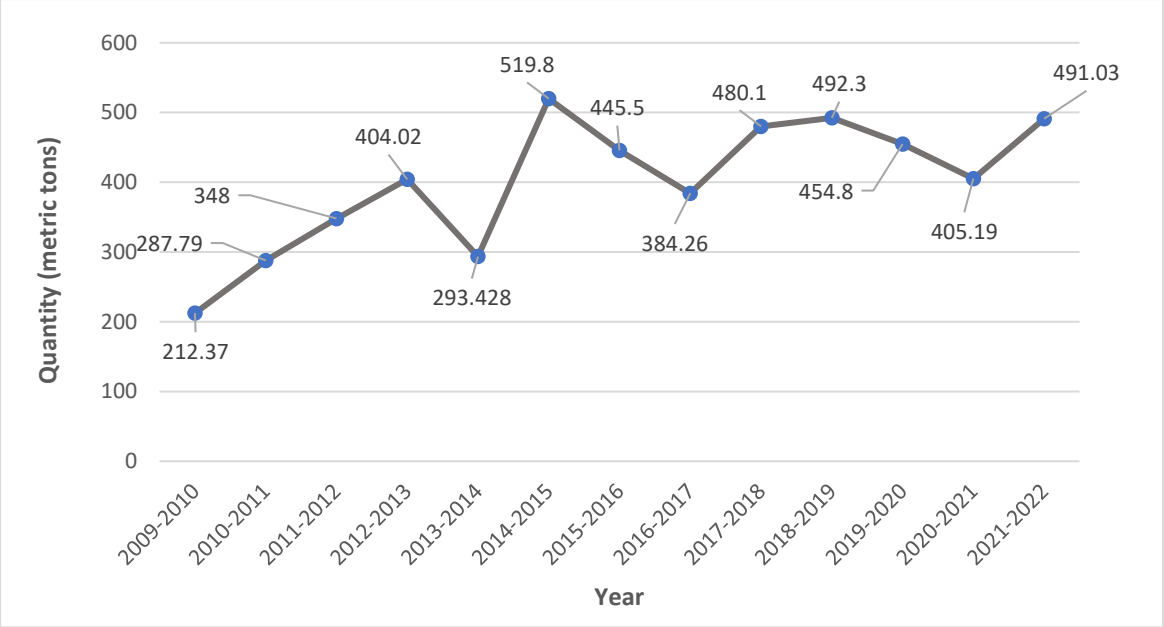

Figure 2. Butachlor distribution trend for 13 years

2.2 Sample size

The Probability Cluster Sampling method was used to sample a representative farmer for the interview. A total of 190 farmers were randomly sampled from 17 gewogs under four dzongkhags for the interview (Table 2).

Table 2. Number of samples and gewogs by dzongkhags

Dzongkhag	Gewogs (no.)	Number of farmers (no.)
Punakha	4	50
Paro	4	50
Thimphu	1	40
Wangduephodrang	8	50
Total	17	190

2.3 Data collection

Farmers' perceptions of the development of weedicide resistance (Butachlor) of weeds were collected through a combination of qualitative and quantitative questionnaires. The survey questionnaire was created using the open-source digital application known as Epicollect5, which facilitated an easy and convenient survey process. The survey took place in August and October 2022, with one farmer from each sampled household being interviewed according to the questionnaire.

2.4 Data analysis

The collected data were analysed using Microsoft Excel and the Statistical Package for Social Sciences (SPSS) version 22. Descriptive statistics, frequency analysis, and graphs were utilized to determine weed management practices employed by farmers and perception of weed resistance development to Butachlor. Correlation analyses were also conducted to examine the relationship between the dosage of Butachlor application and the development of resistance in weeds.

3 Result & Discussion

3.1 Demography

Table 3 and Table 4 present the demographic details of the respondents, including their age and gender. The results indicate that out of the total respondents (n=190), 61.6% (n=117) were female while 38.4% (n=73) were male. The average age of the respondents was 50.9 years, with the youngest respondent being 24 years old and the oldest respondent being 84 years old.

Table 4 presents the household size, agricultural experience, and education background of the respondents. The results show that the maximum household size was 8 persons per household, while the minimum was 1 person. The average household size was three persons per household, including only permanent residents and excluding school-going children.

In terms of education, most of the respondents had no formal education, accounting for 63.2% (n=120) of the total respondents. Non-formal education was received by 20% (n=38) of the respondents, while 16.8% (n=32) had attended formal education in schools. The survey also revealed that most of the respondents had extensive agricultural experience, with 95.3% (n=181) having more than 5 years of experience. Only a small percentage, 4.7% (n=9), had been involved in agriculture farming for less than 5 years.

Table 3. Age of respondent and household size

		Age	HH_size
N	Valid	190	190
Mean		50.90	3.56
Median		52.00	3.00
Minimum		24.00	1
Maximum		85.00	8

Table 4. Gender, education background and agriculture experience

Gender	Number (n)	Percentage (%)
Male	73	38.4
Female	117	61.6
Education Background		
Uneducated	120	63.2
Non-formal	38	20
Educated	32	16.8
Agriculture Experience		
< 5 years	9	4.7
>5 years	181	95.3

The gender disparity reflects the significant role of women in agricultural activities, particularly in rice cultivation, which is labour-intensive. The high participation of women in the survey underscores their importance in the agricultural sector and highlights the need for gender-sensitive approaches in agricultural development programmes. The age distribution suggests that the study involved a diverse group of participants with varying levels of experience and perspectives.

The inclusion of respondents from different age groups can provide a holistic understanding of how farming practices and perceptions may evolve over time. A smaller household size appears to be closely associated with labour shortages, which, in turn, contributes to the heightened reliance on herbicides for weed management in paddy fields(Gianessi, 2013). Furthermore, it is noteworthy that a significant proportion of farmers with no formal education may also play a role in the increased use of herbicides, possibly owing to a lack of historical records or knowledge regarding herbicide application in previous years.

3.2 Land holding

According to the survey, the households owned a total of 269.88 acres of wetland, of which 238.38 acres (88.4%) were cultivated. The average landholding for wetland and dryland was 1.42 acres and 0.42 acres, respectively, while the maximum landholding was 6 acres for wetland and 4.67 acres for dryland. Among the respondents, 85 leased in 103.56 acres of wetland, and 31.5 acres (11.6%) were left fallow due to various reasons. The primary reason for leaving the land fallow was the shortage of irrigation water (n=27), followed by labour shortage (n=8), crop damage by wildlife (n=6) and fragmented land (n=2) (Figure 3).

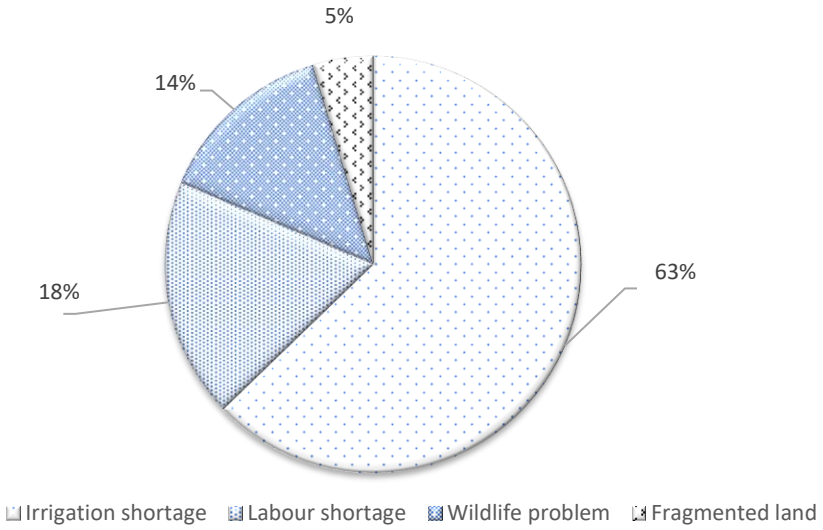

Figure 3. Reasons for keeping the land fallow

Landholding and land use patterns are crucial factors in agricultural practices, as they can significantly impact farming strategies and overall productivity. The presence of fallow land due to irrigation water shortages signals the need for improved water management practices, such as efficient irrigation system to optimize land use and minimize the weed management constraints. Since flooding of rice field is the most effective cultural practice for weed control in lowland rice and maintaining constant water height of 8-15 cm prevents the germination of most weed seeds and kills most emerged weed seedlings (Ismaila, Wada, Daniya, & Gbanguba, 2013). In many smallholder schemes, limited irrigation water can be major constraints to effective weed control (Johnson, 1996). Additionally, addressing labour shortages and wildlife-related challenges may require community-based solutions and support to enhance the rice productions.

3.3 Important weeds in Paddy

The weed species *Potamogeton disctinctus*, locally known as *shochum* in Bhutan was the most recorded species. As shown in Figure 4, out of the 190 farmers surveyed, 176 reported *P. distinctus* in their paddy fields, and it was also found to be the most dominant weed. The second most recorded weed species was *Schoenoplectiella juncoides* (n=172), followed by *Pontederia vaginalis* (n=138), *Acmella uliginosa* (n=114), *Cyperus difformis* (n=106), *Echinochloa crusgalli* (n=89), *Cynodon dactylon* (n=72), and *Bidens tripartita* (n=68). The least common weed species was *Alternanthera sessilis* (n=8). Thirty-two respondents reported the presence of other weed species, including *Fibristylis spp*., *Lemna minor*, *Eriocoulon spp*., *Echinochloa colona*, and *Cyperus rotundus*.

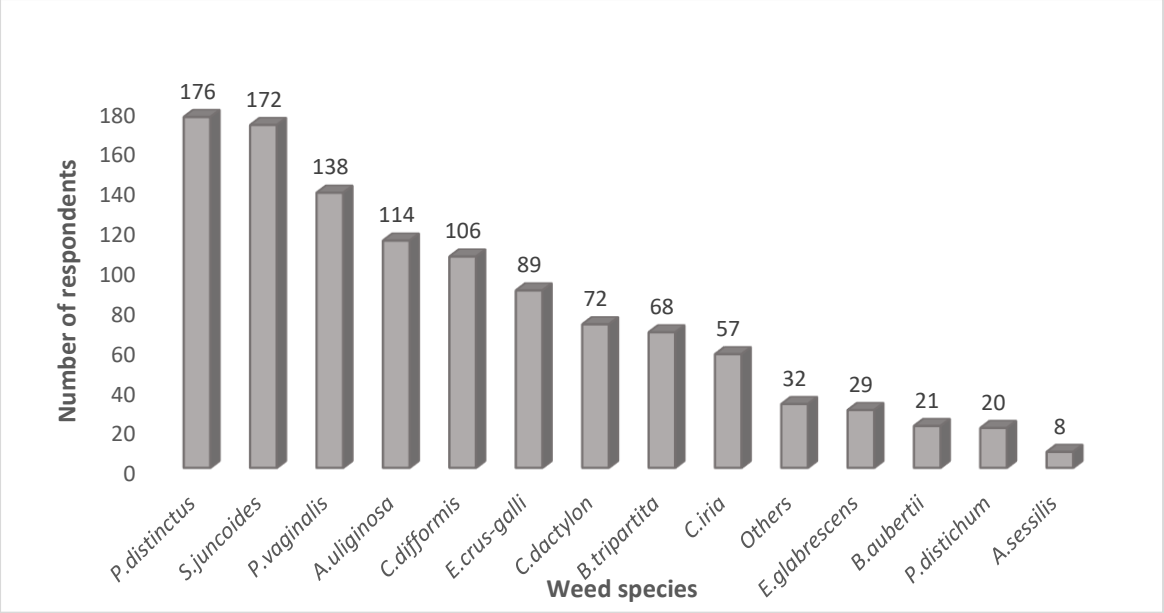

Figure 4. Ranking of important weed species in paddy

The result provided valuable insights into the most important weed species encountered by paddy farmers in the surveyed regions. The dominance of *P. distinctus* suggests that it is a prevalent and persistent weed species in the paddy field of western Bhutan (Dorji, Lhamo, Chophyll, & Tobgye, 2013). Its ability to establish itself in paddy fields can significantly interfere with rice growth and yield. The prevalence of diverse weed species underlines the complexity of weed populations in paddy fields and the need for multifaceted weed management strategies. Recognizing the prevalence and dominance of these diverse weed species is crucial for designing effective weed management strategies that can help minimize weed-related yield losses and promote sustainable paddy cultivation practices (MacLaren, Storkey, Menegat, Metcalfe, & Dehnen-Schmutz, 2020). Further research may delve into the biology, ecology, and control measures specific to these important weed species to enhance the resilience and productivity of paddy farming systems in Bhutan.

3.4 Weed management practices

Farmers in the study area used various methods to manage weeds in their paddy fields as presented in Figure 5. The majority (93%, n=177) practiced an integrated weed management approach that involved hand weeding, cultural methods such as good tillage and ploughing in winter, and herbicide application. A small proportion (6%, n=12) used a combination of hand weeding and herbicide, while only 1% relied solely on manual weeding, which is considered the best management practice despite its laborious and challenging nature.

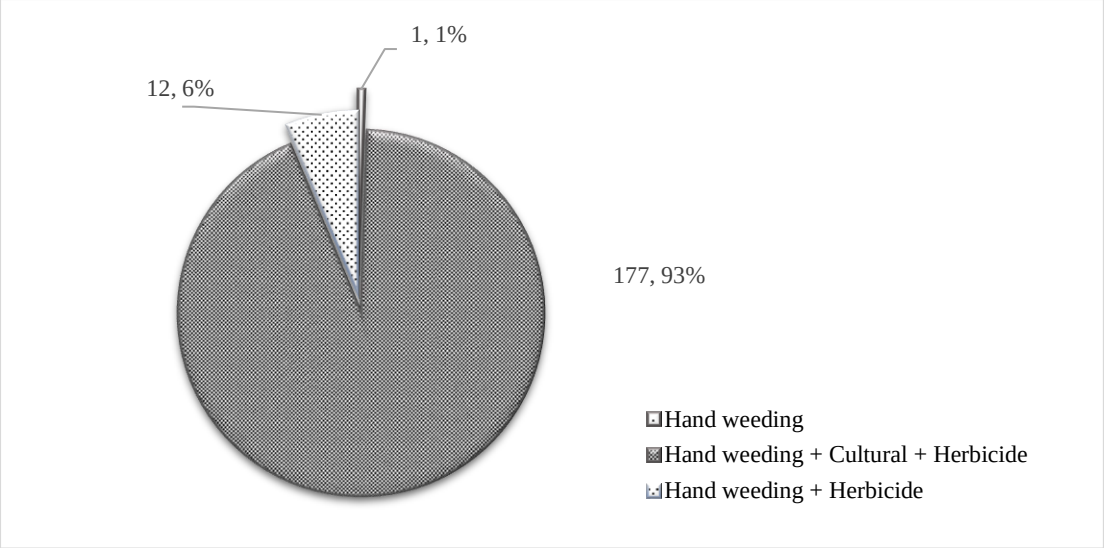

Figure 5. Types of weed management practiced

The farmers used different herbicides to manage weeds in their paddy fields (Table 5). Among the three herbicides commonly used, Butachlor 5% GR and Ethoxysulfuron 15% WDG are used by 168 farmers (88.4%). Butachlor 5% GR was used by 10% (n=19), while one farmer in Shelgana, Punakha dzongkhag, used only Ethoxysulfuron 15% WDG. Two farmers in Rubesa, Wangdue Dzongkhag, used all three herbicides (Butachlor 5% GR, Ethoxysulfuron 15% WDG, and Glyphosate 41 SL) to manage weeds. The two diverse herbicide use patterns suggest that farmers are open to exploring different options to address weed-related challenges. This approach may reflect specific weed management needs or variations in weed species and resistance patterns across different paddy fields.

Table 5. Types of herbicides used by farmers

Herbicides type	Respondents number	%
Butachlor 5% GR	19	10
Ethoxysulfuron 15%WDG	1	0.5
Butachlor + Ethoxysulfuron	168	88.4
Butachlor + Ethoxysulfuron + Glyphosate	2	1.1

3.5 Butachlor usage

The survey findings reveal that butachlor has been used in the field for more than three decades, with a maximum usage period of 40 years and a minimum of 3 years, as reported by farmers. The average duration of butachlor usage was 21 years. However, despite its widespread use, most of the farmers 55.27% (n=105) were not aware of the actual dosage recommended by the

National Plant Protection Centre (NPPC), which is 10 kg per acre. Only 85 respondents (44.74%) knew the recommended dosage of butachlor. The results in Figure 6 showed that 85% (n=161) of the respondents applied butachlor more than the recommended dosage, while only 10% (n=19) used the recommended dosage, and 5% (n=10) used it in lesser amounts than the recommended dosage.

All the respondents reported applying butachlor once during a paddy season, with 147 applying it within 2-5 days after transplanting (DAT), and 26 applying it on the same day of transplantation. However, 5 respondents applied it before transplantation, and 12 farmers applied it within 5 to 15 days after transplanting, which is not recommended by NPPC.

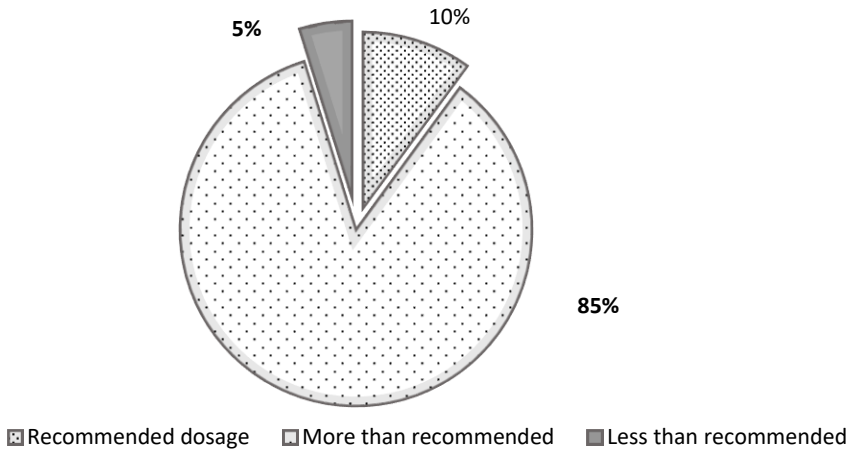

Figure 6. Dosage of butachlor used by farmers

In the study, 65.79 % of the respondents (n=125) reported an increase in the dosage of Butachlor by 30-40% from the recommended amount over the years. Only 26.85 % (n=51) respondents reported using a consistent amount each year, while 7.37% (n=14) had decreased their application rate by switching to Ethoxysulfuron 15% WDG application due to significant issues with broadleaved weeds. The farmers had increased the dosage of butachlor application since the recommended dosage did not effectively control the weeds, potentially attributed to increased weed diversity or development of weed resistance over time.

Among the total respondents, 86.85% (n=165) reported a decline in the effectiveness of Butachlor over time, with 11.05% (n=21) indicating no change in the effectiveness of Butachlor. Whereas none of the respondent reported an increase in effectiveness. A small percentage, 2.10% (n=4) of respondents, expressed uncertainty about Butachlor's effectiveness. The ineffectiveness of Butachlor may be attributed to the intensive and continuous use of the same herbicide for more than two decades. This prolonged practice has

the potential to foster herbicide resistance, thereby contributing to the diminished effectiveness of the herbicide in controlling weeds (Ofosu et al., 2023)

Despite significant proportions of respondents, 86.85% (n=165), reporting a decline in the effectiveness of Butachlor over time, 138 respondents said they would not be able to grow paddy without it, while 45 respondents believed they could cultivate paddy without its application. Seven respondents were unsure.

Regarding the replacement of Butachlor, 118 (62.10%) of the respondents believed it was time to switch to other effective weedicides; 58 (30.53%) believed Butachlor did not need to be replaced, and 14 (7.37%) were unsure whether it should be replaced or not.

The results from the Butachlor usage emphasize the complex dynamics surrounding Butachlor usage in paddy farming. While Butachlor has been a long-standing and indispensable tool for weed management, its misuse and declining effectiveness necessitate a careful re-evaluation of its use. A comprehensive approach, encompassing farmer education and research on alternative weed management strategies are vital to prevent weed resistance development and effective weed management in paddy (Monteiro & Santos, 2022).

3.7 Farmers' perception on butachlor's efficacy

As presented in Figure 7, 51% (n=96) of the respondents reported that the weeds have developed resistance to butachlor, whereas 33% (n=63) reported that weeds have not developed resistance to butachlor, and 16% (n=31) were unsure about the development of resistance to butachlor.

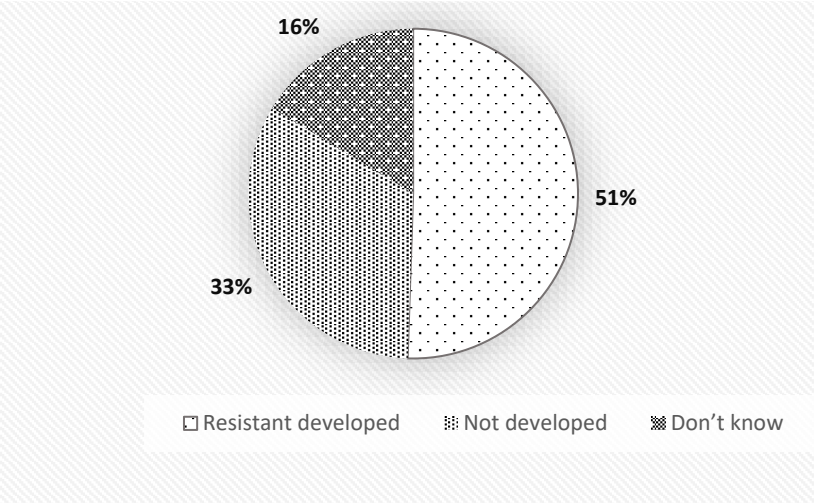

Figure 7. Farmers' perception on resistant development of butachlor to weeds of paddy

To assess the relationship between the variables of dosage increase or decrease and resistance development, Pearson correlation coefficient was computed. The result revealed a weak positive correlation between the two variables, with r (190) = .229, and the correlation was statistically significant (p=.002). These findings suggest that as dosage increases, there is a weak positive association with resistance development.

Several factors may contribute to this observed correlation. Firstly, increasing the dosage of herbicides can exert a selection pressure on weed populations, favouring the survival and proliferation of individuals with natural resistance or adaptive mechanisms. Over time, this can lead to a higher prevalence of resistant weed biotypes (Hanson et al., 2011). Secondly, the relationship could be influenced by other factors, such as weed management practices, weed species present, and the history of herbicide use in the specific fields. It is essential to consider other variables and potential confounding factors that might contribute to this phenomenon. In the surveyed areas, where Butachlor has been utilized for over two decades with a steady increase in application rate of Butachlor, farmers' hypotheses regarding resistance development appear plausible. Supporting this, instances of Butachlor-resistant *E. crus-galli* have been documented in China (Huang and Lin, 1993), with a notable increase in resistance observed after 8-12 years of Butachlor application and corresponding dosage escalation.

The implications of these findings are significant for sustainable weed management in paddy fields. Farmers and agricultural authorities should be aware of the potential consequences of indiscriminate herbicide use, particularly in terms of the development of resistance in weed populations. Integrated weed management strategies that incorporate multiple approaches, including herbicide rotation and cultural practices are necessary to mitigate the development and spread of herbicide-resistant weeds (Ofosu et al., 2023).

4 Conclusion

This study reveals that farmers use Butachlor 5% GR in higher doses than recommended dose, primarily to control grasses and sedges in paddy fields. The study also found that the effectiveness of Butachlor 5% GR has declined over time, and the farmers perceive it because of weed resistance development. However, further research is necessary to validate these claims and findings. The shortage of water for irrigation is the primary reason for leaving the land fallow, followed by the labour shortages. Among the major weeds reported by farmers, *Potamogeton distinctus* was the most common, followed by *Schoenoplectiella juncoides*, *Pontederia vaginalis*, and *Acmella uliginosa*.

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