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Impact of Crop Diversity on Dietary Diversity Among Farmers in India During the COVID-19 Pandemic

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Crop diversity is thought to have small, positive impacts on dietary diversity among farming households, particularly when market access is restricted. Policy responses to the COVID-19 pandemic severely restricted market access. To date, no study has explored the relationship between crop and dietary diversity in this context. To address this gap, we used longitudinal data collected from 833 farmers across 12 states in India at three time points between May and August 2020. Dietary diversity was measured using a modified version of the FAO Minimum Dietary Diversity score for women, which has been used in representative samples of the Indian population in both men and women. Eight food groups were included: (1) starchy staples (rice, wheat, and potatoes), (2) pulses, (3) nuts, (4) vegetables, (5) fruits, (6) dairy, (7) eggs, and (8) fleshy foods (meat, poultry, and fish). Multivariate polynomial logistic regression was used to estimate the association between crop and dietary diversity. Models were adjusted for educational attainment, caste, farm size, having a kitchen garden, and livestock ownership. Participants were, on average, 42.2 years old and 94.2% were male. Dietary diversity decreased over the study period, especially between baseline and follow-up 1, when lockdown measures were the most restrictive (34.2% of participants experienced a decline compared to 16.1% from follow-up 1 to follow-up 2). Compared to farmers who cultivated 1 crop (monocroppers), farmers who cultivated 2 crops or 3 or more crops were significantly less likely to experience a decline in dietary diversity from baseline to follow-up 1: adjusted relative risk (RR) (95% confidence interval [CI]), 0.52 (0.35, 0.78) and 0.48 (0.31, 0.75), respectively. There was no significant association between crop diversity and change in dietary diversity from follow-up 1 to follow-up 2, when phased re-opening had begun. These findings suggest that farmers with greater crop diversity in India were more resilient to market disruptions from the COVID-19 pandemic. Thus, while the links between crop and dietary diversity may be small under normal circumstances, diversifying production systems may play an increasingly important role, as there is greater uncertainty due to global events such as pandemics and climate change.

Keywords: agriculture, biodiversity, crop diversity, nutrition, nutrition-sensitive agriculture, minimum dietary diversity, South Asia

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INTRODUCTION

At the onset of the COVID-19 pandemic, India imposed the world's largest national lockdown. In addition to physical disruptions in the transport of agricultural products and restrictions on the movement of labor, the loss of livelihoods in urban centers resulted in a drop in demand, particularly for high-value products such as fruit, vegetables, and animal-source foods. Before the pandemic, farmers in India were already experiencing economic distress (NABARD, 2018) and carried the greatest malnutrition burden (Ministry of Health and Family Welfare, 2016). Understanding the impact of COVID-19 on agricultural production and diet quality among farmers is critical to informing targeted government action in the context of this pandemic and future shocks.

There are multiple pathways from agriculture to nutrition (Dizon et al., 2021); among them, the link between crop diversity and dietary diversity has been a major focus of research in the past 10 years. However, a recent meta-analysis of 45 studies from 26 countries found little evidence that diversifying production has a meaningful impact on dietary diversity—and if it does, the impact is very small (Sibhatu and Qaim, 2018). In India, two studies have found small, positive associations between crop diversity and dietary diversity (Bhagowalia et al., 2012; Singh et al., 2020), but three have found no association (Chinnadurai et al., 2016; Kavitha et al., 2016; Gupta et al., 2020a). All of these studies were cross-sectional. Nonetheless, the Government of India has prioritized nutrition-sensitive agriculture and especially the diversification of crops by bolstering "traditional" crops such as millets (Irani, 2019). Therefore, continuing to elucidate the relationship between crop diversity and dietary diversity is important in this context.

There are two pathways by which crop diversification can influence dietary diversity: (1) through own-consumption and (2) through household income and the purchasing of food from markets (Dizon et al., 2021). The first of these pathways is important when access to markets is limited, such was the case during the COVID-19 lockdown. Since consumption of food produced on-farm is generally low in India and markets play an influential role in improving dietary diversity (Nandi et al., 2021), studying the impact of the lockdown on dietary diversity among farmers provides unique insights into the role of crop diversity on farmer nutrition when market access is restricted. To date, no study has evaluated the association of crop diversity and dietary diversity in the context of the COVID-19 pandemic and prior to the pandemic, very few studies evaluated this association longitudinally. Given the need for immediate action to mitigate the impact of the COVID-19 lockdown on food and nutrition security, and widespread interest in crop diversification as a means to improve diets and nutritional outcomes, including from the Government of India, such evidence is timely and has immediate policy and programmatic impacts. Our aim was to quantify the association between crop diversity (number of crops cultivated in Kharif [monsoon] 2020) and change in dietary diversity over the course of the pandemic (May to August 2020). We hypothesized that farming households cultivating a greater diversity of crops would be less likely to experience a decline in dietary diversity as the pandemic progressed.

METHODS

Survey Sample

Details of the study design have been published elsewhere (Jaacks et al., 2021). Briefly, participant recruitment was initiated through a list of contacts generated by a civil society organization network. Snowball sampling was used to contact additional farmers beyond those on this initial list. We recruited participants from the top 12 agricultural producing states in India: Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Telangana, Uttar Pradesh, and West Bengal. To participate, respondents had to be 18 years or older and belong to an agricultural household, which could be any combination of the following: own land, harvest a crop in the past month irrespective of land ownership, earn a daily wage or contract-based wage from agricultural labor, or earn an income from livestock or fishing.

The baseline survey was conducted from 3 to 15 May 2020. The first follow-up survey was conducted from 3 to 19 June 2020 and the second follow-up survey from 20 July to 12 August 2020. Thus, the baseline survey coincided with the Rabi (winter) season harvest and both follow-up surveys coincided with the Kharif (monsoon) season sowing. With regards to how these dates aligned with the COVID-19 pandemic and government response, the baseline survey coincided with the nation-wide complete lockdown that started on 25 March 2020. Both follow-up surveys were conducted at a time when phased re-opening was occurring, starting on 8 June 2020. Also at that time, many states began distributing take-home rations through the Public Distribution System (PDS) beyond normal coverage.

Ethics

The study protocol was reviewed and approved by the Harvard T.H. Chan School of Public Health Institutional Review Board (Protocol #: IRB20-0689) and the Public Health Foundation of India Institutional Ethics Committee (Protocol #: TRC-IEC 438/20). Verbal informed consent was obtained from all participants.

Data Collection

Survey interviews were carried out over the phone and responses were recorded by trained enumerators using Qualtrics (Qualtrics, Provo, Utah, USA). The baseline survey took ∼15–30 min to complete, and the follow-up 1 and 2 surveys took ∼20 and 10 min to complete, respectively. The survey instrument was translated into eight languages and enumerators assigned to each state were native speakers of the language spoken there.

This analysis focused on survey questions relating to cropping patterns and diet. Questions on cropping patterns were adapted from Government of India surveys (Ministry of Statistics and Programme Implementation, 2013; Agriculture Census, 2016) with input from agricultural experts. Respondents reported cultivated land area in local units, and these were converted to hectares. At baseline (Rabi), we only asked about the primary crop harvested (defined as the crop for which the participant made the most money) and the total land harvested for that crop. During follow-up, we asked about all different types of crops sown and the land sown for each of these crops in Kharif 2020 and

2019. Given the distribution of the number of crops cultivated in Kharif (**Supplementary Figure 1**), we categorized participants as cultivators of 1 crop, 2 crops, or 3 or more crops. The primary exposure variable was crop diversity category in Kharif 2020.

We used dietary diversity in our assessment because it is an important predictor of adequate nutrient intake and a proxy for diet quality (Miller et al., 2020). Questions on diet were derived from the FAO's Minimum Dietary Diversity for Women (MDD) (FAO, 2016). Eight food groups were included: (1) starchy staples (rice, wheat, and potatoes), (2) pulses, (3) nuts, (4) vegetables, (5) fruits, (6) dairy, (7) eggs, and (8) fleshy foods (meat, poultry, and fish). Vegetables and fruits were not divided further into dark green leafy vegetables and vitamin A-rich fruits and vegetables vs. other vegetables and fruits because we were conducting telephone interviews and had to simplify the survey as much as possible to maximize participant engagement and data quality. Those who consumed a food group every day in the past week were assigned a value of "1" and those who did not were assigned a value of "0" and the values across these eight food groups were summed. Thus, the dietary diversity score ranged from 0 to 8 with 8 representing maximum dietary diversity. Low dietary diversity was defined as MDD$<$4 and high dietary diversity was defined as MDD $>=$ 4. The two primary outcomes were changes in dietary diversity from (1) baseline to follow-up 1 and (2) follow-up 1 to follow-up 2, categorized as no change, decrease, or increase.

Covariates included respondent age, educational attainment, household size, having children under 5 years of age in the household, caste, farm size, livestock ownership, and having a kitchen garden. These covariates were determined through a literature review of the association between crop diversity and dietary diversity (Adjimoti and Kwadzo, 2018; Deb and Bayes, 2018; Gupta et al., 2020a). The minimum adjustment set was determined using a Directed Acyclic Graph (**Supplementary Figure 2**) and DAGitty software (Textor et al., 2016). Respondent age, educational attainment, household size, livestock ownership, and farm size were recorded at baseline. Livestock ownership included owning any number of the following: cows/buffalo/oxen/bulls, poultry, or goats/sheep. Farm size was categorized according to land ownership as: landless (0 ha), small/marginal farms (0.01–2.00 ha), medium farms (2.01–4.00 ha), and large farms ($>$4.00 ha) (Agriculture Census, 2016). Information on respondent's caste, having children under 5 years of age in the household, and having a kitchen garden were recorded at follow-up 1.

Statistical Analysis

Data management and statistical analyses were carried out using STATA version 16 (StataCorp, College Station, Texas, USA). A $p < 0.05$ was considered statistically significant. We conducted a complete-case analysis. Baseline demographic characteristics were compared between those included in the complete-case analysis and those lost to follow-up using chi-square tests for categorical variables and *t*-tests for continuous variables. Descriptive statistics were used to summarize demographic characteristics of participants (age, educational attainment, household size, children under 5 years of age in the household, and caste), livestock ownership, having a kitchen garden, and farm size, for the total sample and according to (1) change in dietary diversity from baseline to follow-up 1 and (2) crop diversity in Kharif 2020. We described changes over time in both crop and dietary diversity and tested for differences over time using chi-square tests for categorical variables and one-way ANOVA for continuous variables.

The association between crop diversity in Kharif 2020 and change in dietary diversity between (1) baseline and follow-up 1 and (2) follow-up 1 and follow-up 2 was estimated using multivariate polynomial logistic regression. Models were adjusted for educational attainment, caste, farm size, kitchen garden, and livestock ownership as per the minimal adjustment set of covariates from the DAG.

In sensitivity analyses, we constructed the Simpson's Index as an alternate measure of crop diversity that considers both the land area used for cultivation and number of crops cultivated (Adjimoti and Kwadzo, 2018). The Simpson's Index has been previously found to be associated with increased dietary diversity and food security status (Kavitha et al., 2016; Adjimoti and Kwadzo, 2018; Deb and Bayes, 2018; Chegere and Stage, 2020). The total score ranges between 0 and 1 where 0 corresponds to monocropping and 1 to highest achievable crop diversity. It was calculated for landowning farmers using the following equation:

$$\text{Simpson's Index} = 1 - \sum_{1}^{n} P_i^2 \tag{1}$$

where P_i is the area proportion of the i-th crop in the gross cropped area and n is the total number of crops cultivated per farm. We used multivariate polynomial logistic regression adjusting for the same covariates as in our main analysis to assess the association between the Simpson's Index in Kharif 2020 and change in individual dietary diversity.

In an additional sensitivity analysis, because there could potentially be some differences in cropping patterns from 2019 to 2020, we used the same multivariate polynomial logistic regression as for our main analysis but used crop diversity in Kharif 2019 as the exposure in lieu of crop diversity in Kharif 2020.

RESULTS

Participants were, on average, 42.2 years old (range: 18–78 years) and 94.2% were male (**Table 1**). Almost half of participants (46.3%) belonged to 6 or more person households. There were no statistically significant differences between those with complete data ($n = 833$) and those lost to follow-up ($n = 604$) (**Supplementary Table 1**).

Demographic characteristics according to change in dietary diversity from baseline to follow-up 1 are shown in **Table 1**. Those with no change in dietary diversity tended be older, have lower educational attainment, belong to a scheduled caste/tribe, have cultivated 2 crops in Kharif 2020, and have income from wages (all $p < 0.05$; **Table 1**). They also were less likely to have children $<$5 years in the household and a kitchen garden (both $p < 0.05$; **Table 1**). Those with an increase in dietary diversity

TABLE 1 | Demographic characteristics of participants from agricultural households across 12 states in India during the COVID-19 pandemic, according to change in dietary diversity from baseline (May 2020) to follow-up 1 (June 2020) ($n = 833$).

	Total ($n = 833$)	**No change in dietary diversity* ($n = 421$)**	**Decrease in dietary diversity* ($n = 285$)**	**Increase in dietary diversity* ($n = 127$)**	***P*-value†**
Gender					
Male	94.2 (785)	93.3 (393)	94.4 (269)	96.9 (123)	0.33
Female	5.8 (48)	6.7 (28)	5.6 (16)	3.1 (4)	
Age, years	42.2 (12.5)	43.4 (12.6)	41.1 (12.5)	40.7 (11.6)	0.02
Household size					
1–3	9.8 (82)	10.2 (43)	8.8 (25)	11.0 (14)	0.15
4	23.3 (194)	27.1 (114)	21.1 (60)	15.7 (20)	
5	20.5 (171)	19.5 (82)	21.8 (62)	21.3 (27)	
6 or more	46.3 (386)	43.2 (182)	48.4 (138)	52.0 (66)	
Educational attainment					
No formal schooling/primary school	33.3 (277)	38.5 (162)	24.6 (70)	35.7 (45)	0.01
Secondary school	38.2 (318)	36.1 (152)	43.2 (123)	34.1 (43)	
Grad/post grad/professional	28.5 (237)	25.4 (107)	32.3 (92)	30.2 (38)	
Caste					
Scheduled caste/tribe	23.6 (195)	29.3 (123)	16.0 (45)	21.3 (27)	0.01
Backward caste	37.2 (308)	33.8 (142)	41.6 (117)	38.6 (49)	
Other/no answer	39.3 (325)	36.9 (155)	42.3 (119)	40.2 (51)	
Children <5 years, % yes	34.5 (287)	28.7 (121)	38.9 (111)	43.3 (55)	0.01
Farm size					
Landless (0 ha)	6.4 (53)	6.9 (29)	6.8 (19)	4.0 (5)	0.21
Small/marginal (0.01–2.00 ha)	51.2 (423)	48.7 (205)	54.3 (152)	52.8 (66)	
Medium (2.01–4.00 ha)	18.9 (156)	21.4 (90)	13.9 (39)	21.6 (27)	
Large (>4.00 ha)	23.5 (194)	23.0 (97)	25.0 (70)	21.6 (27)	
Crop diversity (Kharif 2020)					
1 crop	45.4 (352)	38.0 (149)	61.8 (162)	33.9 (41)	<0.01
2 crops	28.0 (217)	31.9 (125)	22.1 (58)	28.1 (34)	
3 or more crops	26.6 (206)	30.1 (118)	16.0 (42)	38.0 (46)	
Simpson's index‡	0.24 (0.26)	0.29 (0.27)	0.15 (0.23)	0.29 (0.26)	<0.01
Livestock ownership, % yes	76.8 (640)	78.1 (329)	74.4 (212)	78.0 (99)	0.48
Income from livestock, % yes	26.7 (171)	28.6 (94)	24.1 (51)	26.3 (26)	0.51
Income from wages, % yes	32.0 (259)	35.7 (147)	25.2 (70)	35.0 (42)	0.01
Received food rations, % yes	47.5 (394)	47.1 (198)	51.2 (146)	40.0 (50)	0.11
Kitchen garden, % yes	55.0 (458)	47.7 (201)	65.3 (186)	55.9 (71)	<0.01

Values are percent (n) or mean (SD).

**Dietary diversity score calculated based on consumption of eight food groups over the past 7 days including: (1) starchy staples (rice, wheat, and potatoes), (2) pulses, (3) nuts, (4) vegetables, (5) fruits, (6) dairy, (7) eggs, and (8) fleshy foods (meat, poultry, and fish). Those who consumed a food group every day in the past week were assigned a value of "1" and those who did not were assigned a value of "0" and the values across these eight food groups were summed. Thus, the dietary diversity score ranged from 0 to 8 with 8 representing maximum dietary diversity.*

†P-value from chi-square test for categorical variables and one-way ANOVA for continuous variables.

‡Simpson's Index calculated using the equation: Simpson's Index = $1 - \sum_1^n P_i^2$ where P_i is the area proportion of the i-th crop in the gross cropped area and n is the total number of crops cultivated per farm. Values range from 0 to 1 where 0 corresponds to monocropping and 1 to the highest achievable crop diversity.

tended to be younger, have children <5 years in the household, and to have cultivated 3 or more crops in Kharif 2020 (all $p < 0.05$; **Table 1**). Those who experienced a decrease in dietary diversity had higher levels of education, were least likely to belong to a scheduled caste/tribe, and were most likely to have cultivated 1 crop in Kharif 2020 and have a kitchen garden (all $p < 0.05$; **Table 1**).

Demographic characteristics according to crop diversity in Kharif 2020 are shown in **Table 2**. Those who cultivated 1 crop in Kharif 2020 had higher educational attainment, were more likely to belong to other/no answer caste category, and to have a kitchen garden, and less likely to have income from wages and own livestock (all $p < 0.05$; **Table 2**). Those who cultivated 2 crops were most likely to own a large farm ($p = 0.03$; **Table 2**). Those who cultivated 3 or more crops tended to have lower educational attainment and were most likely to belong to a scheduled caste/tribe, own livestock, and earn an income from wages,

TABLE 2 | Demographic characteristics of participants from agricultural households across 12 states in India during the COVID-19 pandemic, according to number of crops cultivated in Kharif 2020 ($n = 775$).

	Total ($n = 775$)	**Cultivated 1 crop ($n = 352$)***	**Cultivated 2 crops ($n = 217$)***	**Cultivated 3 or more crops ($n = 206$)***	***P*-value†**
Gender					
Male	95.2 (738)	93.5 (329)	96.8 (210)	96.6 (199)	0.111
Female	4.8 (37)	6.5 (23)	3.2 (7)	3.0 (7)	
Age, years	42.41 (12.57)	42.45 (13.15)	41.62 (12.95)	43.15 (11.05)	0.458
Household size					
1–3	9.5 (74)	11.1 (39)	10.1 (22)	6.3 (13)	0.501
4	22.7 (176)	21.6 (76)	23.5 (51)	23.8 (49)	
5	20.4 (158)	21.9 (77)	17.5 (38)	20.9 (43)	
6 or more	47.4 (367)	45.5 (160)	48.8 (106)	49.0 (101)	
Educational attainment					
No formal schooling/primary school	31.1 (241)	23.6 (83)	34.1 (74)	41.0 (84)	<0.001
Secondary school	39.1 (303)	41.8 (147)	36.9 (80)	37.1 (76)	
Grad/post grad/professional	29.7 (230)	34.7 (122)	29.0 (63)	22.0 (45)	
Caste					
Scheduled caste/tribe	21.7 (167)	11.2 (39)	26.4 (57)	34.5 (71)	<0.001
Backward caste	39.1 (301)	40.2 (140)	37.5 (81)	38.8 (80)	
Other/no answer	39.2 (302)	48.6 (122)	36.1 (78)	26.7 (55)	
Children <5 years, % yes	34.8 (270)	33.8 (119)	34.1 (74)	37.4 (77)	0.669
Farm size					
Landless (0 ha)	2.8 (22)	1.7 (6)	2.3 (5)	5.3 (11)	0.032
Small/marginal (0.01–2.00 ha)	52.3 (405)	54.5 (192)	53.2 (115)	47.6 (98)	
Medium (2.01–4.00 ha)	20.2 (156)	19.6 (69)	16.2 (35)	25.2 (52)	
Large (>4.00 ha)	24.7 (191)	24.1 (85)	28.2 (61)	21.8 (45)	
Crop diversity (Kharif 2019)					
1 crop	47.6 (362)	96.0 (332)	10.8 (23)	3.5 (7)	<0.001
2 crops	26.5 (217)	3.5 (12)	81.7 (174)	7.9 (16)	
3 or more crops	25.9 (197)	0.6 (2)	7.5 (16)	88.6 (179)	
Simpson's index‡	0.54 (0.17)	0 (0)	0.36 (0.18)	0.17 (0.54)	<0.001
Livestock ownership, % yes	79.4 (615)	75.6 (266)	78.3 (170)	86.9 (179)	0.006
Income from livestock, % yes	26.3 (162)	28.9 (77)	22.4 (38)	26.3 (47)	0.313
Income from wages, % yes	28.6 (216)	23.4 (78)	30.6 (66)	35.1 (72)	0.010
Received food rations, % yes	45.2 (349)	45.6 (160)	46.5 (100)	43.2 (89)	0.778
Kitchen garden, % yes	55.0 (458)	68.8 (242)	49.3 (107)	46.6 (96)	<0.001

Values are percent (n) or mean (SD).

[*] *Crop diversity was calculated based on the number of crops cultivated by a farmer in Kharif 2020.*

[†] *P-value from chi-square test for categorical variables and one-way ANOVA for continuous variables.*

[‡] *Simpson's Index calculated using the equation: Simpson's Index = 1 −* $\sum_{1}^{n} P_i^2$ *where* P_i *is the area proportion of the i-th crop in the gross cropped area and n is the total number of crops cultivated per farm. Values range from 0 to 1 where 0 corresponds to monocropping and 1 to the highest achievable crop diversity.*

and least likely to have a kitchen garden (all $p < 0.05$; **Table 2**).

With regards to changes in cropping patterns over time, 96.0% of farmers who cultivated 1 crop in 2020 had cultivated 1 crop in 2019 ($p < 0.001$; **Table 2**). Very few farmers had increased the number of crops cultivated from 2019 to 2020 (6.0%; data not shown) and even fewer had decreased the number of crops cultivated over that period (3.9%; data not shown). Comparing crop type, those cultivating only 1 crop in Kharif 2020 were mostly cultivating paddy (**Figure 1**). However, among those cultivating 3 or more crops, the most popular crop was pulses. In Kharif 2019, cropping patterns were slightly different. While farmers who cultivated 1 crop were disproportionately growing paddy in 2019, a larger proportion of farmers were also cultivating vegetables, soybeans, and pulses than in 2020. Among farmers growing 3 or more crops in 2019, the most popular crops were pulses and paddy.

Low dietary diversity (MDD<4) had a prevalence of 78.9% at baseline, 88.6% at follow-up 1, and 88.0% at follow-up 2 (data not shown). With regards to changes in dietary diversity over time, MDD decreased from baseline to follow-up 1 and slightly increased from follow-up 1 to follow-up 2: MDD (mean ± SD)

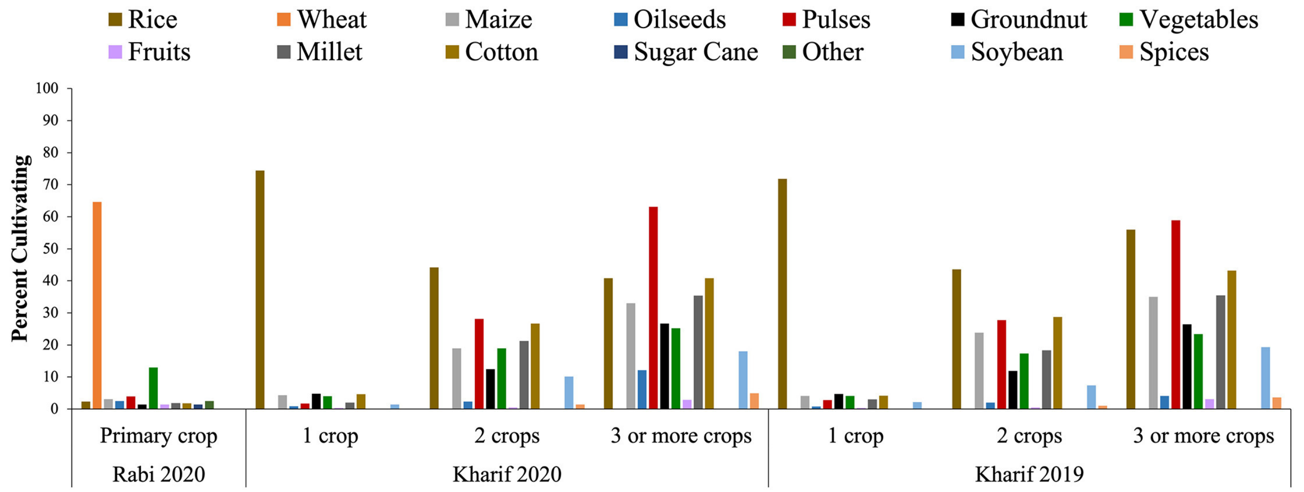

FIGURE 1 | Crops contributing to crop diversity over time in participants from agricultural households across 12 states in India during the COVID-19 pandemic (*n* = 775 for Kharif 2020; *n* = 761 for Kharif 2019; *n* = 515 for Rabi 2020).

2.33 ± 1.24 at baseline compared to 2.05 ± 1.03 at follow-up 1 and 2.11 ± 1.00 at follow-up 2 (data not shown). From baseline to follow-up 1, dietary diversity decreased for 34.2%, and from follow-up 1 to follow-up 2, it decreased for 16.1% (data not shown). Among participants with low dietary diversity, starches, dairy, and vegetables were the food groups consumed most frequently, and there was a slight decline in consumption of vegetables over time (**Figure 2**). Among participants with high dietary diversity, grains, dairy, vegetables, and pulses were the food groups consumed most frequently, and there was a slight decline in consumption of fruits and slight increase in consumption of meat/poultry/fish and eggs over time (**Figure 2**).

Compared to farmers who cultivated 1 crop, farmers who cultivated 2 crops or 3 or more crops were significantly less likely to experience a decline in dietary diversity from baseline to follow-up 1: adjusted relative risk (RR) (95% confidence interval [CI]), 0.52 (0.35, 0.78) and 0.48 (0.31, 0.75), respectively (**Table 3**). Farmers who cultivated 3 or more crops were significantly more likely to experience an increase in dietary diversity from baseline to follow-up 1 compared to farmers who cultivated 1 crop: RR (95% CI), 1.71 (1.01, 2.88). There was no significant association between crop diversity and change in dietary diversity from follow-up 1 to follow-up 2, when phased re-opening had begun (**Table 3**).

With regards to the association of food-security related covariates (kitchen garden and livestock) with change in dietary diversity, those with a kitchen garden were significantly less likely to experience a decline in dietary diversity from baseline to follow-up 1 and from follow-up 1 to follow-up 2, compared to those without a kitchen garden: RR (95% CI), 0.43 (0.30, 0.61) and 0.52 (0.34, 0.81), respectively (**Table 3**). However, those with a kitchen garden were less likely to experience an increase in dietary diversity from follow-up 1 to follow-up 2 (phased re-opening period) than those without a kitchen garden: RR (95% CI), 0.53 (0.35, 0.79). Livestock ownership was not significantly associated with dietary diversity in this sample.

Results were consistent with the Simpson's Index as a measure of crop diversity: those with a higher Simpson's Index (indicating greater crop diversity) were less likely to experience a decrease in dietary diversity from baseline to follow-up 1 but no significant effect was observed from follow-up 1 to follow-up 2 (**Supplementary Table 2**). Similarly, results were consistent when crop diversity in Kharif 2019 was evaluated in place of Kharif 2020 in sensitivity analyses (**Supplementary Table 3**).

DISCUSSION

This paper is the first longitudinal analysis to examine the association of crop diversity with dietary diversity in the context of the COVID-19 pandemic. We found that in the initial lockdown period, when measures were most restrictive, crop diversity was protective against declines in dietary diversity. Having a kitchen garden was also protective against a decline in dietary diversity. While crop diversity was no longer significantly associated with dietary diversity during later stages of the lockdown when restrictions were lifted, having a kitchen garden remained protective during this stage. Livestock ownership was not associated with dietary diversity at any time point. In sum, these findings suggest that farmers with greater crop diversity in India were more resilient to market disruptions from the COVID-19 pandemic. Thus, while the links between crop diversity and dietary diversity may be small under normal circumstances, diversifying production systems may play an important role in resiliency when major market disruptions occur.

Five previous studies, including one systematic review focused on South Asia, have quantified the association between crop diversity and dietary diversity in India (Bhagowalia et al., 2012; Chinnadurai et al., 2016; Kavitha et al., 2016; Gupta et al., 2020a;

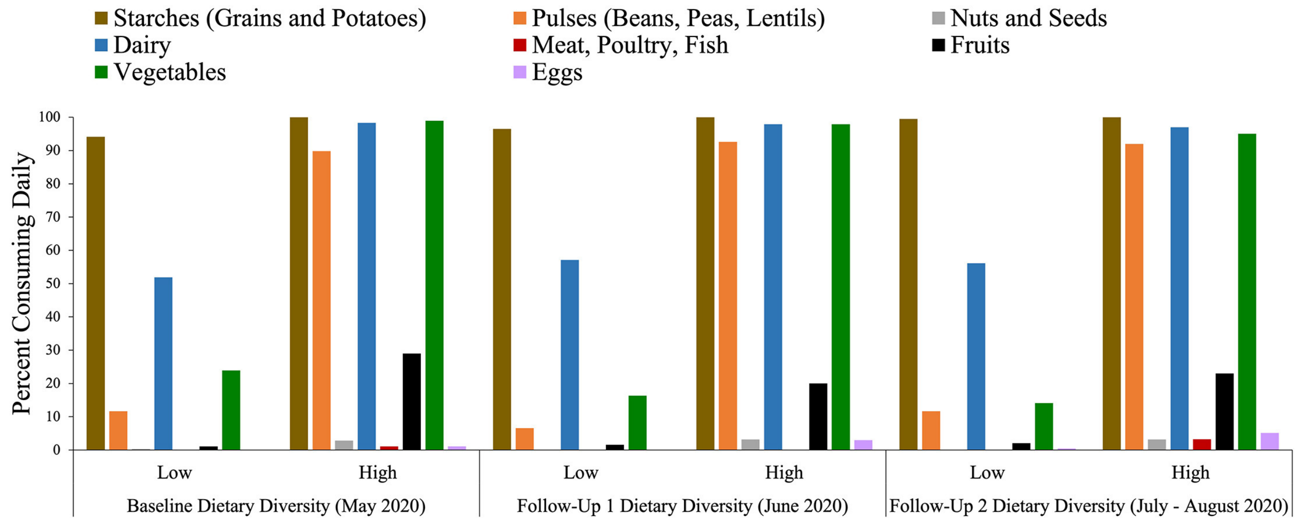

FIGURE 2 | Food groups contributing to low vs. high dietary diversity over time in participants from agricultural households across 12 states in India during the COVID-19 pandemic ($n = 833$). Low dietary diversity defined as <4 dietary diversity score and high dietary diversity defined as ≥4 dietary diversity score out of a total of 8.

Singh et al., 2020; Dizon et al., 2021). Cross-sectional, nationally representative data from 2004/2005 indicated that crop diversity was positively associated with dietary diversity (beta coefficient from OLS regression was 0.32, $p < 0.01$), especially intake of pulses, and the effect was slightly larger among marginal/small farmers as compared to large farmers (Bhagowalia et al., 2012). In contrast, a panel study of two representative cross-sections of Tamil Nadu (2004/2005 and 2012/2013) found no consistent association between crop diversity and dietary diversity (Chinnadurai et al., 2016). Similarly, after adjustment for confounding factors, an analysis of six villages in Telangana and Maharashtra participating in the Indian Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Village Level Studies found no association between crop diversity and dietary diversity (Kavitha et al., 2016). The lack of or inconsistent evidence for the association between crop and dietary diversity motivated the exploration of this association longitudinally in the context of COVID-19. We build on these previous efforts by demonstrating that this association may be most prominent in the wake of a shock to the food supply chain, and that the strength of this association may vary over time.

Previous studies have found that access to food markets influences dietary diversity, potentially to a greater extent than crop diversity (Nandi et al., 2021). Rural communities may not be able to access markets offering diverse food options due to factors such as distance, transportation, and purchasing power, and this may in turn increase their vulnerability to poor nutritional outcomes (Nandi et al., 2021). In India, where farmers often purchase food that is not grown on their own farm to complement their meals, market access plays an important role in increasing dietary diversity (Galab and Vijaya Kumar, 2011; Ludwig, 2018). During the initial COVID-19 lockdown in India, restrictions resulted in a complete disruption to food market access as farmers and markets alike were required to suspend all activities (Sinha, 2021). The shock to the food supply chain resulting from the lockdown presented an unprecedented opportunity to study the longitudinal association between crop and dietary diversity in the near absence of market access. Our results suggest that farmers growing 2 or more crops in the wake of the abrupt government shutdown were protected from a decrease in dietary diversity, suggesting resilience to market access disruptions.

We also observed that participants with a kitchen garden were less likely to experience a decline in dietary diversity for the entire study period. Prior to the COVID-19 pandemic, several intervention studies had found that kitchen gardens were associated with increased dietary diversity in India (Pradhan et al., 2018; Suri, 2020; Vijayalakshmi and Swamy, 2020). In this respect, kitchen gardens may have complemented on-farm production, acting as a dietary buffer to limited market access during the lockdown or reduced income in later stages. An intervention study comparing baseline dietary intake data from 2013/14 to post-intervention in 2016/17 found a significant increase in fruit and vegetable consumption following the introduction of nutrition garden in the state of Odisha in India (Pradhan et al., 2018). Notably, weekly consumption of green leafy vegetables almost tripled when comparing pre- and post- intervention (Pradhan et al., 2018). Similar results were observed after the introduction of a "nutri garden" intervention in Andhra Pradesh (Vijayalakshmi and Swamy, 2020). However, not all studies of kitchen gardens in India have found significant effects (Gupta et al., 2020a). Our study findings with regards to kitchen gardens being protective is particularly timely as kitchen gardens (a.k.a. "nutri gardens") are now being promoted by the Ministry of Women and Child Development and several state governments including, for example, Andhra Pradesh.

TABLE 3 | Association between crop diversity and dietary diversity in participants from agricultural households across 12 states in India during the COVID-19 pandemic ($n = 833$).

	Baseline to follow-up 1 (May to June 2020)		**Follow-up 1 to follow-up 2 (June to August 2020)**	
	Increase in dietary diversity*	**Decrease in dietary diversity***	**Increase in dietary diversity***	**Decrease in dietary diversity***
Crop diversity (Kharif 2020)				
1 crop	Ref	Ref	Ref	Ref
2 crops	1.10 (0.64, 1.86)	**0.52 (0.35, 0.78)**	0.90 (0.56, 1.44)	1.07 (0.65, 1.76)
3 or more crops	**1.71 (1.01, 2.88)**	**0.48 (0.31, 0.75)**	0.80 (0.48, 1.33)	1.11 (0.66, 1.87)
Covariates				
Education				
No formal schooling/primary school	Ref	Ref	Ref	Ref
Secondary school	0.99 (0.60, 1.64)	**1.81 (1.19, 2.75)**	1.29 (0.80, 2.10)	**1.80 (1.08, 3.01)**
Grad/post grad/Professional	1.29 (0.76, 2.19)	**1.81 (1.15, 2.84)**	**2.15 (1.30, 3.58)**	**1.97 (1.13, 3.43)**
Caste				
Scheduled caste/tribe	0.68 (0.37, 1.24)	0.60 (0.36, 1.01)	1.34 (0.74, 2.41)	0.81 (0.44, 1.48)
Backward caste	1.05 (0.64, 1.72)	1.14 (0.77, 1.69)	1.59 (0.99, 2.55)	0.79 (0.49, 1.27)
Other/no answer	Ref	Ref	Ref	Ref
Farm size				
Landless (0 ha)	0.65 (0.17, 2.47)	0.82 (0.27, 2.23)	2.27 (0.84, 6.16)	0.97 (0.25, 3.79)
Small/marginal (0.01–2.00 ha)	Ref	Ref	Ref	Ref
Medium (2.01–4.00 ha)	0.81 (0.47, 1.39)	**0.55 (0.35, 0.88)**	**0.37 (0.21, 0.67)**	0.74 (0.43, 1.27)
Large (>4.00 ha)	0.76 (0.44, 1.31)	0.82 (0.53, 1.25)	**0.30 (0.17, 0.52)**	0.63 (0.38, 1.06)
Livestock ownership				
No	Ref	Ref	Ref	Ref
Yes	1.08 (0.83, 1.40)	1.11 (0.90, 1.37)	0.88 (0.69, 1.13)	0.85 (0.65, 1.11)
Kitchen garden				
No	Ref	Ref	Ref	Ref
Yes	0.71 (0.46, 1.10)	**0.43 (0.30, 0.61)**	**0.53 (0.35, 0.79)**	**0.52 (0.34, 0.81)**

Values are adjusted relative risk (95% confidence interval) from multivariate polynomial logistic regression. Bold values indicate statistical significance at the $p < 0.05$ level.

**Dietary diversity score calculated based on consumption of eight food groups over the past 7 days including: (1) starchy staples (rice, wheat, and potatoes), (2) pulses, (3) nuts, (4) vegetables, (5) fruits, (6) dairy, (7) eggs, and (8) fleshy foods (meat, poultry, and fish). Those who consumed a food group every day in the past week were assigned a value of "1" and those who did not were assigned a value of "0" and the values across these eight food groups were summed. Thus, the dietary diversity score ranged from 0 to 8 with 8 representing maximum dietary diversity.*

Interestingly, we did not find a significant association between livestock ownership and dietary diversity in this sample. Livestock ownership may impact dietary diversity through acting as a source of animal-source foods but also through the generation of income (Dizon et al., 2021). Similar to kitchen gardens, livestock ownership is typically viewed as a complement to crop diversity in enhancing dietary diversity. One study in India found that livestock ownership was positively associated with dietary diversity only in women but not the household (Gupta et al., 2020a). Livestock ownership has also been found to be associated with dietary diversity outside of India, especially in women (Ambikapathi et al., 2019; Zanello et al., 2019). Given our null finding, we hypothesize that the high prevalence of livestock ownership (>75%) and dairy consumption (>50%) in this sample did not allow for much room for improvement. Therefore, our null result may be due to lack of variation in exposure rather than a true lack of impact.

In addition to the COVID-19 pandemic, farmers in India simultaneously faced climate-related disruptions that resulted in crop loss (Sarkar, 2020). Heat waves, a "super cyclone," and erratic rainfall impeded transportation and placed an additional obstacle to accessing markets and the sale of agricultural products during this period (Meyers, 2020; The New Indian Express, 2020). The effects of climate change are projected to place a substantial burden on farmers in India and already do, as they struggle to adapt to erratic weather patterns (Srivastava et al., 2010; Sinha and Bhogal, 2021). Moving forward, adaptation strategies to enhance resilience to natural disasters will be critical to ensuring nutritional security among farming households in India. Promoting the production of diverse crops represents a potential course of action that may mitigate the impact of unexpected shocks to production and market access on farmer diets.

These results should be interpreted while considering several limitations. First, this is an observational study, and while we adjusted for all measured confounders, the possibility of residual confounding remains. For example, we did not explicitly measure market access (i.e., distance to nearest market or availability of transport). However, as described above, market access was substantially disrupted due to the lockdown and therefore may have been less of a confounder in this context. In addition, the small sample size of women and pregnant women prevented us from exploring gender as an effect modifier or adjusting for it as a potential confounder. Women's nutritional knowledge has been found to be an important determinant of individual and household dietary diversity (Gupta et al., 2020a). We are also unable to comment on on gender disparities in dietary diversity within farming households. It is plausible that the lockdown impacted women's dietary diversity more severely because of prevailing gender norms around distribution of food among household members (Gupta et al., 2020b). Despite these limitations, this study was strengthened by its longitudinal design and novelty–being one of the first studies to evaluate this association in the context of the COVID-19 pandemic, and in a country where a large proportion of the world's malnourished live.

This is an especially timely analysis given the recent agricultural policy environment in India. Three new agriculture bills have been passed which led to widespread protests across the country, but especially in the northern states of Punjab and Haryana (India's so-called "breadbasket") (Sharma, 2020). The protests are at least in part due to speculation that procurement at Minimum Support Price (MSP) will decrease as a result of these bills. The Government of India hopes that these bills will lead to increased investment in infrastructure support for perishable commodities while also ensuring price stabilization. This could help farmers become less dependent on MSP-supported crops (e.g., rice and wheat) and increase diversification toward high-value crops, with potentially positive impacts on dietary diversity of farming households (Aujla, 2020). The Ministry of Women and Child Development has also emphasized the need to diversify crop production as part of POSHAN Abhiyaan (the Prime Minister's Overarching Scheme for Holistic Nutrition) with the development of Bhartiya Poshan Krishi Kosh, a web portal mapping district-level crop diversity (Press Information Bureau, 2020).

In conclusion, we found that increased crop diversity was associated with improved dietary diversity among farmers in the first stage of the COVID-19 lockdown in India, when measures were most restrictive. However, this association was not significant for the latter half of the study period, when restrictions were eased. Our findings suggest that crop diversity most likely blunted the initial impact of the lockdown on dietary diversity among farmers. Kitchen gardens may play an important role in supporting diverse diets when on-farm production is low, or market access is limited. This has immediate policy implications for government response to COVID-19 and other abrupt shocks to the food supply and market access. Such market access restrictions are predicted to become more frequent and severe in the wake of climate-related disasters and future pandemics. Crop diversity may be an effective strategy to building resilience to and mitigating the effects of disasters on diets and nutrition. In understanding the parallels between the COVID-19 pandemic with other calamities of large scale, we can inform policies that work to safeguard food security, nutrition, and health through promotion of diverse crop production systems.

DATA AVAILABILITY STATEMENT

De-identified participant data are available in the Harvard Dataverse: https://doi.org/10.7910/DVN/JZ511O.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Harvard T. H. Chan School of Public Health Institutional Review Board (Protocol #: IRB20-0689) and Public Health Foundation of India Institutional Ethics Committee (Protocol #: TRC-IEC 438/20). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

LJ, GR, AR, DV, and PP conceived of the study. LJ and KC secured funding. KC conducted the data analysis under the supervision of LJ. KC wrote the initial draft of the manuscript with guidance from LJ. AR, GR, PP, and DV provided feedback on the manuscript. All authors read and approved the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2021.695347/full#supplementary-material

REFERENCES

Adjimoti, G. O., and Kwadzo, G. T. M. (2018). Crop diversification and household food security status: evidence from Rural Benin. *Agri. Food Security* 7:82. doi: 10.1186/s40066-018-0233-x

Agriculture Census (2016). *Agriculture Census 2016*. Available online at: https://agricoop.nic.in/en/divisiontype/agriculture-census (accessed April 20, 2021).

Ambikapathi, R., Gunaratna, N. S., Madzorera, I., Passarelli, S., Canavan, C. R., Noor, R. A., et al. (2019). Market food diversity mitigates the effect of environment on women's dietary diversity in the agriculture to nutrition (ATONU) study, Ethiopia. *Publ. Health Nutr.* 22, 2110–2119. doi: 10.1017/S136898001900051X

Aujla, I. S. (2020). *Does MSP Stall Crop Diversification? - Times of India. The Times of India*. Available online at: https://timesofindia.indiatimes.com/india/does-msp-stall-crop-diversification/articleshow/78399992.cms (accessed April 20, 2021).

Bhagowalia, P., Headey, D., and Kadiyala, S. (2012). *Agriculture, Income, and Nutrition Linkages in India: Insights From a Nationally Representative Survey*. Washington, DC: International Food Policy Research Institute.

Chegere, M. J., and Stage, J. (2020). Agricultural production diversity, dietary diversity and nutritional status: panel data evidence from Tanzania. *World Dev.* 129:104856. doi: 10.1016/j.worlddev.2019.104856

Chinnadurai, M., Karunakaran, K. R., Chandrasekaran, M., Balasubramanian, R., and Umanath, M. (2016). Examining linkage between dietary pattern and crop diversification: An evidence from Tamil Nadu. *Agri. Econ. Res. Rev.* 29:149. doi: 10.5958/0974-0279.2016.00042.2

Deb, U., and Bayes, A. (2018). *Crop Diversity, Dietary Diversity and Nutritional Outcome in Rural Bangladesh: Evidences from VDSA Panel Household Surveys*, Vol. 2018. LANSA Working Paper Series. Brighton, UK: Institute of Development Studies.

Dizon, F., Josephson, A., and Raju, D. (2021). Pathways to better nutrition in South Asia: Evidence on the effects of food and agricultural interventions. *Global Food Security* 28:100467. doi: 10.1016/j.gfs.2020.100467

FAO (2016). *Minimum Dietary Diversity for Women- A Guide to Measurement*. Rome: FAO.

Galab, S., and Vijaya Kumar, S. (2011). *The Impact of Growth on Childhood Poverty in Andhra Pradesh: Initial Findings from India: Round 3 Survey Report*. Oxford: Young Lives, Department of International Development, University of Oxford.

Gupta, S., Sunder, N., and Pingali, P. (2020a). Market access, production diversity, and diet diversity: Evidence from India. *Food Nutr. Bull.* 41, 167–185. doi: 10.1177/0379572120920061

Gupta, S., Sunder, N., and Pingali, P. L. (2020b). Are women in rural India really consuming a less diverse diet? *Food Nutr. Bull.* 41, 318–331. doi: 10.1177/0379572120943780

Irani, S. (2019). *The Indian Express*. Available online at: https://indianexpress.com/article/opinion/columns/a-jan-aandolan-for-nutrition-6124546/ (accessed April 20, 2021).

Jaacks, L. M., Veluguri, D., Serupally, R., Roy, A., Prabhakaran, P., and Ramanjaneyulu, G. V. (2021). Impact of the COVID-19 pandemic on agricultural production, livelihoods, and food security in India: Baseline results of a phone survey. *Food Secur*. 13, 1–17. doi: 10.1007/s12571-021-01164-w

Kavitha, K., Soumitra, P., and Padmaja, R. (2016). Understanding the linkages between crop diversity and household dietary diversity in the semi-arid regions of India. *Agri. Econ. Res. Rev.* 29, 129–137. doi: 10.5958/0974-0279.2016.00040.9

Ludwig, T. (2018). *An Egg for an Egg and a Bean for a Bean? How Production Diversity Determines Dietary Diversity of Smallholder Farmers in Rural India*. Rochester, NY: Social Science Research Network.

Meyers, T. (2020). One *Pandemic, Two Cyclones: In India, Aid Groups Respond Amid the Damage.* Available online at: https://www.directrelief.org/2020/06/one-pandemic-two-cyclones-in-india-aid-groups-respond-amid-the-damage/ (accessed June 17, 2020).

Miller, V., Webb, P., Micha, R., and Mozaffarian, D. (2020). *Defining Diet Quality: A Synthesis of Dietary Quality Metrics and Their Validity for the Double Burden of Malnutrition*. Available online at: https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(20)30162-5/fulltext (accessed April 20, 2021).

Ministry of Health and Family Welfare (2016). *National Family Health Survey-4 (NFHS-4): India Fact Sheet*. New Delhi: Government of India.

Ministry of Statistics and Programme Implementation (2013). *National Sample Survey (NSS), 70th Round*. New Delhi: Government of India.

NABARD (2018). *NABARD*. Available online at: https://www.nabard.org/PressReleases-article.aspx?id=25&cid=554&NID=43 (accessed April 20, 2021).

Nandi, R., Nedumaran, S., and Ravula, P. (2021). The interplay between food market access and farm household dietary diversity in low and middle income countries: a systematic review of literature. *Global Food Security* 28:100484. doi: 10.1016/j.gfs.2020.100484

Pradhan, A., Sathanandhan, R., Panda, A. K., and Wagh, R. (2018). *Improving Household Diet Diversity Through Promotion of Nutrition Gardens in India*. Available online at: https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/13816 (accessed April 20, 2021).

Press Information Bureau (2020). *Ministry of Women and Child Development. Bhartiya Poshan Krishi Kosh*. Delhi: PIB, Government of India.

Sarkar, S. (2020). *Farmers Hammered by Unseasonal Rain, Covid-19 Lockdown. India Climate Dialogue*. Available online at: https://www.eco-business.com/news/farmers-hammered-by-unseasonal-rain-covid-19-lockdown/ (accessed April 10, 2020).

Sharma, M. G. (2020). *Explained: What Punjab's Three New Farm Bills Say, and What They Seek to Achieve. The Indian Express*. Available online at: https://indianexpress.com/article/explained/explained-what-punjabs-three-new-farm-bills-say-what-they-seek-to-achieve-6813386/ (accessed December 3, 2020).

Sibhatu, K. T., and Qaim, M. (2018). Farm production diversity and dietary quality: linkages and measurement issues. *Food Sec.* 10, 47–59. doi: 10.1007/s12571-017-0762-3

Singh, S., Jones, A. D., and Jain, M. (2020). Regional differences in agricultural and socioeconomic factors associated with farmer household dietary diversity in India. *PLoS ONE* 15: e0231107. doi: 10.1371/journal.pone.0231107

Sinha, D. (2021). Hunger and food security in the times of Covid-19. *J. Soc. Econ. Dev*. 45, 1–4. doi: 10.1007/s40847-020-00124-y

Sinha, S., and Bhogal, S. (2021). *India Protests: Farmers Could Switch to More Climate-Resilient Crops – but They Have Been given No Incentive*. Available online at: http://theconversation.com/india-protests-farmers-could-switch-to-more-climate-resilient-crops-but-they-have-been-given-no-incentive-154700 (accessed April 20, 2021).

Srivastava, A., Naresh Kumar, S., and Aggarwal, P. K. (2010). Assessment on vulnerability of sorghum to climate change in India. *Agri. Ecosyst. Environ.* 138, 160–169. doi: 10.1016/j.agee.2010.04.012

Suri, S. (2020). *Nutrition Gardens: A Sustainable Model for Food Security and Diversity*. Available online at: https://www.orfonline.org/research/nutrition-gardens-a-sustainable-model-for-food-security-and-diversity-67933/ (accessed April 20, 2021).

Textor, J. B., van der Zander, M. S., Gilthorpe, Liskiewicz, M., and Ellison, G. T. (2016). Robust causal inference using directed acyclic graphs: the R package 'dagitty.' *Int. J. Epidemiol.* 45, 1887–1894. doi: 10.1093/ije/dyw341

The New Indian Express (2020). *Farmers Demand Relief for Crops Damaged by Cyclone. The New Indian Express*. Available online at: https://www.newindianexpress.com/states/tamil-nadu/2020/may/21/farmers-demand-relief-for-crops-damaged-by-cyclone-2146193.html (accessed April 20, 2021).

Vijayalakshmi, K., and Swamy, G. (2020). A study on nutritional security and economic empowerment of women through homestead nutrigardens in Nellore District of Andhra Pradesh. *Pharma Innov. J.* 9, 207–212.

Zanello, G., Shankar, B., and Poole, N. (2019). Buy or make? Agricultural production diversity, markets and dietary diversity in Afghanistan. *Food Policy* 87:101731. doi: 10.1016/j.foodpol.2019.101731

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.