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A scientometric study on prevalence of gastrointestinal parasites in pigs (*Sus scrofa*) of India

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ABSTRACT

In this study, prevalence of the gastrointestinal (GI) parasites in pigs from India was estimated by employing scientometrics. The prevalence studies on the GI parasites of pigs (n=21) were acquired from online and offline databases (timeline: 2010-2021) and meta-analysis was performed using meta package in R-software. The prevalence of GI parasites in pigs was 54% (95% level: CI 39-69%, PI 5-96% of 8,921 samples tested) in India. A higher prevalence of 81% was reported in 2010 than the recent years (2016-21). The highest prevalence in South zone (78%), and least in West zone (35%) was observed. The prevalence of GI parasites was highest in Tamil Nadu (96%) and lowest in Maharashtra (28%). The higher prevalence was observed in protozoa (30%) than other parasite classes and lower in cestodes (4%) in pigs. More number of studies have been reported on nematode parasites indicating its importance in pigs. A higher prevalence was observed in the studies conducted on samples (84%) collected from slaughterhouse than the faecal samples (46%) in pigs. Among the parasite species, coccidia (29%) were most commonly reported whereas *Globocephalus urosubulatus* (0.7%) was observed sporadically low. Amongst nematodes and trematodes, a higher prevalence in *Ascaris* spp. (27%) and Amphistomes (12%), correspondingly was observed. The high GI parasites prevalence zones, states, parasite classes, sample types and parasite species recognized will assist the stakeholders and decision makers, in control and preventive approaches. Further, this study provides the baseline information on GI parasites prevalence in pigs of India for devising effective deworming strategies which ultimately lead to beneficial piggery in India.

Keywords: Gastrointestinal parasites, India, Meta-analysis, Pigs, Prevalence, Systematic review

India has the major livestock resources in the world, which plays a fundamental role in rural economy and their livelihood. Among various livestock species, pigs are fast growing and one of the most prolific livestock species and find an important place as they are being reared by economically and socially weaker population (Balasubramanyam *et al*. 2020). Pigs, as compared to other livestock species, have a great potential to contribute for the easy and short period economic return to the farmers, because of certain inherent traits like high productivity, better-feed conversion efficiency, early maturity and short generation interval. Pig industry has major role in the production of more animal origin protein, increased employment opportunities, alleviation of poverty, support the National Gross Domestic Product and economic development generation (Gomathi *et al.* 2016). Pigs grow under different agro-climatic conditions because of their wide adaptability (Balasubramanyam *et al*. 2020). According to the 20th livestock census 2019, total pig population was 9.06 million and has been decreased by 12.03% as compared to the 2012 livestock census (10.29 million). Among the total pig population in 2019, exotic and indigenous breeds of pigs comprise of 1.90 and 7.16 million, respectively (BAHS 2019). The export quantity of meat pigs in India was about 542 tonnes and export value base price was 1,285 USD in 2020 (FAOSTAT 2022). Piggery is a potential source of meat production, bristles and manure. In India, 90% of the pig population are localised in rural areas, where swine domestication is mainly focussed towards low income group families with poor hygiene standards of living as reported (Laha *et al.* 2014). The gastrointestinal (GI) parasites are one of the important disease causing organisms of pigs, and the major risk factors are the poor environmental hygiene and improper management practices followed. In India, majority of pigs are raised under extensive system and fed with raw garbage, kitchen wastes and faecal matter, therefore, pigs are highly prone to parasitic infections (Tiwari *et al*. 2009). In China, USA and Germany the average body weight of pigs were 76, 84 and 90 kg, respectively, whereas in India, it remains around 35 kg as a whole (ICAR 2012). The prevalence of GI parasitic infections in pigs are very common and pigs

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are infected with a wide range of GI parasites with reports from all over the world including India (Laha *et al*. 2014, Dadas *et al*. 2016, Singh *et al*. 2017, Patra *et al*. 2019). The GI parasites also injure some vital organs, which play key role in metabolic activities, and causes anorexia, reduced growth, anemia, emaciation, infertility (Ngowi *et al*. 2004). There are limited number of studies available on the GI parasites prevalence in pigs of India and also from few geographical locations. However, there is no literature available on GI parasite prevalence in pigs from India based on meta-analysis. Hence, an attempt was made to estimate the prevalence of GI parasites based on various sub-groups including year-wise, zone-wise, state-wise, parasite classes, sample types and parasite species-wise in pigs of India.

MATERIALS AND METHODS

Survey of literatures: A systematic literature survey was undertaken on the prevalence of GI parasites in pigs in India by using important keyword searches. The list of databases used for the survey were PubMed, Science Direct, Springer's, Scopus, Google Scholar, Indianjournals.com, J-Gate @ Consortium of e-Resources in Agriculture (CeRA) of Indian Council of Agricultural Research (ICAR), research abstracts in proceedings/ compendium of conferences, seminars, symposia, and different printed works of literature as available recently. To establish the estimation of prevalence, more than 81 publications were searched, investigated, and selected, and the informational data was subjected to meta-analysis. The prevalence studies were divided into five zones namely north, east, west, south, and central, based on the states in India. The information of the author's name, year, state, number of positive samples, number of samples examined, parasite classes, sample types and parasite species identified in pigs were collected accordingly. The studies were retrieved between 2010 to 2021, based on accessibility, and the language was confined to English alone. In addition, the peer-reviewed journals, original research articles, and references cited from the collected studies were re-investigated to back search published literature on prevalence of GI parasite from previous years.

Study selection: The cross-sectional and longitudinal studies on prevalence of GI parasites in pigs of India were chosen. The studies encompassed the following inclusion standards such as: GI parasites frequency, parasites detected, total number of animals tested or screened, year of the study conducted, studies with prevalence values reported, place or location of study, study type and studies that have used the quality methodology of substantiating tests. Exclusion standards for the studies were: GI parasites species frequencies was not reported and studies with case reports, review articles and outbreaks investigations were not used for analysis. As per an earlier report, the quality of the study was evaluated by using a specified quality judging system as reported (Krishnamoorthy *et al.* 2021a, b, c) and it comprises of sample representativeness, sample size, prevalence values, and outcome assessment, with highest scores of 2 for each criterion. Eight was the maximum score for the quality assessment and based on the study necessities the lowest score was decided and included for meta-analysis purpose.

Curation of data: The prevalence studies of GI parasites in pigs were systematically assessed and evaluated before entering in the pre-designed Microsoft Excel sheets. These consisted of the authors' names, year of publication, study duration, number of animals positive for GI parasites, total number of pigs examined, and the confirmation procedure used for GI parasite diagnosis and parasitic species identified. The flotation, sedimentation, and microscopic examination of faecal samples were used to support the diagnosis of GI parasite prevalence. The maximum value of prevalence attained by several parasitic species or over all prevalence obtained in a study was used to calculate the GI parasites prevalence estimates.

Meta-analysis: The scientometrics means the combination of the scientific systematic review and meta-analysis by employing statistical tools. The PRISMA-P checklist was used predominantly for the procedure of systematic regular reviews and meta-analyses that recapitulate the combined data from the studies. The object of PRISMA-P 2015 is to progress the quality of systematic review procedure, parallel to the impact attained by further reporting instructions (Turner *et al.* 2012). To perform the meta-analysis on GI parasite prevalence in pigs of India, the R Open source scripting programme (Comprehensive R Archive Network) version 3.2.5 was used and the R package utilized was "meta" as earlier described (Schwarzer 2007). A forest plot or confidence interval plots was employed to represent the meta-analysis graphically. The analysis was done by using the specified linear mixed model and Logit transformation, i.e.'sm=PLOGIT'. A square stand for a point estimate of prevalence and a horizontal line expanding either side of the square block representing a 95% confidence interval (CI) were utilized to demonstrate the studies. The shaded black line below the forest plot denotes the prediction interval (PI) at the 95% level. The heterogeneity among the studies was established by using the I-square, Tau square, H, and P values obtained and provided in the last line of the forest plot. Sub-group analysis was undertaken based on various characteristics specified earlier to decrease heterogeneity between studies on prevalence of GI parasites (Krishnamoorthy *et al*. 2019a, b, Krishnamoorthy *et al*. 2021a, b, c). The Cochran Q statistics were estimated as described in the earlier studies (Krishnamoorthy *et al*. 2017, Krishnamoorthy *et al*. 2019a, b, Krishnamoorthy *et al*. 2021a, b, c). For the prevalence of GI parasites in pigs, the overall prevalence estimates, year-wise, zone-wise, state-wise, parasite-wise, parasite classes, sample type-wise and parasitic species-wise, the forest plots were prepared. The prevalence estimates for GI parasites in pigs from India was indicated as a percentage and along with CI and PI at 95% level.

RESULTS AND DISCUSSION

Prevalence studies on GI parasites in pigs: The GI parasitism is one of the important health problems affecting the yield of the livestock across the world (Singh *et al.* 2017). After thorough systematic review, a total of 21 prevalence studies from India were considered for a meta-analysis. The details of GI parasites prevalence studies in pigs of India and their quality judgement scores are presented in Table 1. A meta-analysis was carried out on studies having a quality assessment score of five or higher. The particulars of the studies on GI parasites prevalence with year, states, zones, parasite classes, sample types and parasitic species are presented in Tables 2 and 3. The prevalence studies included for meta-analysis were 2, 1, and 17, during 2010, 2014 and 2016-2021, correspondingly with a total of 8,921 samples collected from pigs in India. The zone-wise prevalence studies from India were more in East and South zone (6) followed by North and West zone (4) and Central zone (1). The year-wise and state-wise number of prevalence studies on GI parasites of pigs are depicted in Fig 1. More number of studies were reported during the year 2020 (5) compared to other years. The GI parasites prevalence studies in pigs from India covered 12 states and one union territory, with maximum number of studies reported from Karnataka (4), followed by Maharashtra (3),

Fig. 1. GI parasites prevalence studies based on pigs in India: (a) year-wise and (b) state-wise.

Nagaland and Punjab (2) and one study each from Haryana, Jammu and Kashmir, Manipur, Meghalaya, Mizoram, North east, Rajasthan, Tamil Nadu, Telangana and Madhya Pradesh. The majority of studies on GI parasitic classes were from nematode (20), followed by protozoa (17), trematodes (10) and cestodes (3). More number of studies were reported using faecal samples (17) than the slaughterhouse samples (4). Among the parasitic species,

Table 1. Gastrointestinal parasites prevalence studies in pigs from India and their quality judgement scores

Author and year	State name	Zone	Assessment scores for prevalence studies*				
			Sample size (Maximum score=2)	Sample representativeness (Maximum score=2)	Prevalence value (Maximum score=2)	Outcome of evaluation (Maximum score=2)	Total score (Maximum score=8)
Bhangale *et al.* 2010	Maharashtra	West	1	1	2	1	5
Borkotoky *et al.* 2014	Nagaland	East	1	2	2	1	6
Dadas *et al.* 2016	Maharashtra	West	1	2	2	1	6
Das *et al.* 2020	Meghalaya	East	2	2	2	1	7
Gomathi *et al.* 2016	Tamil Nadu	South	1	1	2	1	5
Gowda *et al.* 2018	Karnataka	South	1	1	2	1	5
Gowda *et al.* 2020	Karnataka	South	1	1	2	1	5
Kalkal and Vohra 2021	Haryana	North	2	2	2	1	7
Kaur *et al.* 2017	Punjab	North	2	2	2	1	7
Khajuria *et al.* 2010	Jammu and Kashmir	North	1	1	2	1	5
Laha *et al.* 2017a	Manipur	East	1	1	2	1	5
Laha *et al.* 2017b	Nagaland	East	1	1	2	1	5
Murthy *et al.* 2016	Karnataka	South	2	1	2	1	6
Navajeevan *et al.* 2021	Telangana	South	1	1	2	1	5
Palampalle *et al.* 2021	Maharashtra	West	1	1	2	1	5
Patra *et al.* 2019	North East	East	2	2	2	1	7
Rajesh *et al.* 2020	Mizoram	East	1	1	2	1	5
Satheesha *et al.* 2020	Karnataka	South	2	2	2	1	7
Sharma *et al.* 2020	Punjab	North	2	1	2	1	6
Singh *et al.* 2017	Madhya Pradesh	Central	1	1	2	1	5
Yadav *et al.* 2021	Rajasthan	West	2	2	2	1	7

Note: *Sample size= 1-Mentioned, 2-Clearly given; Sample Representativeness= 1-Representative, 2-Strictly representative; Prevalence values= 1-Estimated, 2-Mentioned; Outcome assessment= 1-Single evaluation, 2-Double evaluation.

Table 2. Gastrointestinal parasites prevalence in pigs of India based on meta-analysis

No.	Parameter	Period	Number of studies	Total	Prevalence (%) (CI at 95% level)	PI (%) at 95% level	Tests for heterogeneity and values				
							I^2 (%)	Tau square	H	DF	Cochran Q
1.	India	2010-2021	21	8921	54 [39-69]	5-96	98.3	2.031	7.68	20	1804.4**
Period-wise											
2a.	India period-I	2010	2	384	81	-	-	-	1.00	1	0.40^{NS}
2b.	India period-II	2014	1	80	29	-	-	-	-	-	-
2c.	India period-III	2016-2021	17	8457	52 [35-68]	4-96	98.3	2.096	7.65	17	1544.9**
Zone and State-wise											
3.	North Zone	2010-2021	4	1464	52 [32-72]	2-99	98.6	0.715	8.48	3	264.5**
3a.	Haryana	2021	1	50	48	-	-	-	-	-	-
3b.	Jammu and Kashmir	2010	1	310	81	-	-	-	-	-	-
3c.	Punjab	2017 and 2020	2	1104	38 [25-54]	-	97.4	0.191	6.20	1	38.3**
4.	East Zone	2014-2020	6	4166	39 [29-49]	12-73	92.7	0.239	3.69	5	68.7**
4a.	Manipur	2017	1	149	33	-	-	-	-	-	-
4b.	Meghalaya	2020	1	2574	29	-	-	-	-	-	-
4c.	Mizoram	2020	1	68	56	-	-	-	-	-	-
4d.	Nagaland	2014 and 2017	2	222	43 [24-65]	-	94.2	0.352	4.16	1	18.5**
4e.	North east	2019	1	1153	32	-	-	-	-	-	-
5.	West Zone	2010-2021	4	1454	35 [5-84]	0-100	97.8	5.417	6.69	3	591.5**
5a.	Maharashtra	2010-2021	3	685	28 [2-89]	0-100	98.4	6.953	8.03	2	374.6**
5b.	Rajasthan	2021	1	769	57	-	-	-	-	-	-
6.	South Zone	2016-2021	6	1382	78 [60-89]	14-99	95.7	1.038	4.82	5	136.3**
6a.	Karnataka	2016-2020	4	1179	68 [49-83]	4-99	96.6	0.645	5.42	3	95.4**
6b.	Tamil Nadu	2016	1	50	96	-	-	-	-	-	-
6c.	Telangana	2021	1	153	84	-	-	-	-	-	-
7.	Central Zone	2017	1	455	64	-	-	-	-	-	-
7a.	Madhya Pradesh	2017	1	455	64	-	-	-	-	-	-
Parasite classes											
8a.	Cestode	2010-2021	3	252	4 [2-7]	0-73	0.0	0.0	1.00	2	0.15^{NS}
8b.	Nematode	2010-2021	20	5422	26 [17-36]	3-78	94.9	1.199	4.44	19	644.7**
8c.	Protozoa	2010-2021	17	6268	30 [19-44]	3-87	97.8	1.603	6.71	16	1453.6**
8d.	Trematode	2010-2021	10	3655	8 [4-16]	1-57	97.0	1.196	5.81	9	488.9**
Sample type											
9a.	Faecal	2010-2021	17	8486	46 [31-61]	5-93	98.4	1.634	8.00	17	1525.5**
9b.	Slaughter	2016-2021	4	435	84 [63-94]	3-100	94.8	1.096	4.38	3	68.1**

Note: CI, Confidence Interval; DF, Degrees of Freedom; H, Heterogeneity; PI, Prediction Interval. Significance levels: ^{NS}, Not significant; *, Significant (P<0.05); **, Highly significant (P<0.01).

Table 3. Species of Gastrointestinal parasites prevalence in pigs of India based on meta-analysis

No.	Parameter	Period	Number of studies	Total	Prevalence (%) [CI at 95% level]	PI (%) at 95% level	Tests for Heterogeneity				
							I^2 (%)	Tau square	H	DF	Cochran Q
Trematodes											
1.	Order: Echinostomida										
1a.	Amphistomes	2017 and 2020	2	1294	12 [2-46]	-	99.0	1.808	9.86	1	188.9**
1b.	*Dicrocoelium* spp.	2016	1	50	6.2	-	-	-	-	-	-
1c.	*Fasciolopsis* buski	2010-2021	8	2666	7 [4-14]	1-50	94.4	0.938	4.23	7	177.7**
2.	Order: Diplostomida										
2a.	*Schistosoma* spp.	2016-2021	4	783	6 [2-17]	0-93	89.3	1.236	3.05	3	55.7**
Cestodes											
3.	Order: Taeniidea										
3a.	*Cysticercus tenuicollis* (Metacestode of *Taenia hydatigena)*	2021	1	128	3.3	-	-	-	-	-	-
3b.	*Taenia spp.*	2010	1	74	4.0	-	-	-	-	-	-
4.	Order: Anoplocephalidea										
4a.	*Moniezia expansa*	2016	1	50	4.2	-	-	-	-	-	-
Nematodes											
5.	Order: Ascaridida										
5a.	*Ascaris* spp.	2010-2021	18	4796	27 [21-35]	7-65	93.2	0.535	3.84	17	309.2**
5b.	*Syphacia* spp.	2021	1	476	1.0	-	-	-	-	-	-
6.	Order: Enoplida										
6a.	*Capillaria* spp.	2014	1	80	1.2	-	-	-	-	-	-
7.	Order: Rhabditida										
7a.	*Strongyloides* spp.	2010-2021	8	2450	5 [3-8]	1-25	86.4	0.499	2.71	7	61.4**
8.	Order: Spirurida										
8a.	*Ascarops* spp.	2018-2021	5	2157	11 [2-44]	0-99	98.8	4.312	9.16	4	453.9**
8b.	*Physocephalus* spp.	2018-2021	3	950	6 [0-52]	0-100	98.9	5.862	9.67	2	254.8**
8c.	*Simondsia paradoxa*	2018 and 2021	2	225	6 [3-10]	-	0.0	0.0	1.00	1	0.9^{NS}
9.	Order: Strongylida										
9a.	*Ancylostoma* spp.	2016	1	50	8.3	-	-	-	-	-	-
9b.	*Globocephalus urosubulatus*	2016	1	135	0.7	-	-	-	-	-	-
9c.	*Hyostrongylus rubidus*	2016	1	50	4.2	-	-	-	-	-	-
9d.	*Metastrongylus* spp.	2020-2021	2	853	1 [1-2]	-	40.2	0.0	1.29	1	1.5^{NS}
9e.	*Oesophagostomum* spp.	2010-2020	4	352	8 [4-16]	0-68	78.4	0.403	2.15	3	14.6**
9f.	*Stephanurus dentatus*	2019	1	255	2.0	-	-	-	-	-	-
9g.	Strongyles	2010-2021	12	3789	12 [8-20]	2-56	96.2	0.885	5.10	11	365.7**
Protozoa											
10.	Order: Amoebida										

Table 3 (*Concluded*)

No.	Parameter	Period	Number of studies	Total	Prevalence (%) [CI at 95% level]	PI (%) at 95% level	Tests for Heterogeneity				
10a.	*Entamoeba polecki*	2020	1	2574	5.6	-	-	-	-	-	-
11.	Order: Eucoccidiidae										
11a.	coccidia	2010-2021	6	1888	29 [9-63]	0-9	99.2	3.200	10.92	5	1159.2**
11b.	*Cryptosporidium* spp.	2019-2020	3	2897	10 [9-11]	5-20	0.0	0.0	1.00	2	0.3^{NS}
11c.	*Eimeria* spp.	2010-2021	9	4177	20 [13-28]	4-57	94.8	0.436	4.38	8	188.9**
11d.	*Isospora* spp.	2016-2020	5	3163	5 [2-10]	0-39	79.6	0.481	2.21	4	24.0**
12.	Order: Trichomonadida										
12a.	*Giardia* spp.	2019-2020	2	2829	4 [2-9]	-	94.3	0.275	4.21	1	14.5**
13.	Order: Vestibuliferida										
13a.	*Balantidium coli*	2010-2021	13	5661	22 [13-35]	2-80	97.3	1.345	6.07	12	704.0**
Mixed Infection											
14.	Mixed infection	2010-2021	7	2651	18 [11-28]	3-60	94.3	0.487	4.19	6	116.7**

Note: CI, Confidence Interval; DF, Degrees of Freedom; H, Heterogeneity; PI, Prediction Interval. Significance levels: ^{NS}, Not significant; *, Significant (P<0.05); **, Highly significant (P<0.01).

more number of studies were reported in *Ascaris* spp. (18) followed by *Balantidium coli* (13), Strongyles (12), etc. Therefore, *Ascaris* spp. is the important GI parasite in pigs and also affects more number of pigs in India. The parasite species such as *Dicrocoelium* spp*., Taenia* spp*., Moniezia expansa, Syphacia* spp*., Capillaria* spp*., Ancylostoma* spp., *Globocephalus urosubulatus, Stephanurus dentatus* and *Hyostrongylus rubidus* are reported with the single study and these are the least important GI parasitic species of pigs in India.

Prevalence of GI parasites in pigs of India: The details of the prevalence estimates obtained based on the overall, period-wise, zone-wise, state-wise, parasite classes, sample types and parasitic species are presented in Tables 2 and 3. The overall GI parasites prevalence estimate was 54% (95% level, CI 39–69%, PI 5–96%) in pigs of India and concurred with previous reports (Dadas *et al*. 2016, Murthy *et al.* 2016). However, a higher prevalence of GI parasites was 80.64% (Khajuria *et al*. 2010) compared to the present study. The range of GI parasites prevalence in pigs was 11–96%, from various geographical locations in India as reported in various studies (Deka *et al*. 2005, Borthakur *et al.* 2007, Godara and Sharma 2010, Singh *et al*. 2017, Balasubramanyam *et al*. 2020). The forest plot of GI parasites prevalence studies from various states in India reported during the period 2010 to 2021 is depicted in Fig 2. The prevalence of GI parasites was recorded maximum during 2010 (81%) when compared to recent periods, i.e. 2014 (29%) and 2016-21 (52%). The GI parasite prevalence showed decreasing trend when compared to the period 2010 and 2016-2021, this may be due to improvement in the diagnostic techniques and treatment measures of GI parasites in recent years than earlier. The zone-wise and state-wise prevalence of GI parasites of pigs in India are depicted in Fig 3. The zone-wise study disclosed that high prevalence of GI parasites was found in South zone (78%0 and least in West zone (35%). This could be due to the variation in agro-climatic conditions, agro-ecology favouring the growth, survival and spread of infective stages in the pasture, rearing systems of animals and management practices of pigs in that area of specific environment. The maximum prevalence of GI parasites was recorded in Tamil Nadu (96%), followed by Telangana (84%) and Jammu and Kashmir (81%). In spite of having separate shed or pen for various age groups of pigs in Tamil Nadu, the prevalence estimate was higher in the reported study (Balasubramanyam *et al*. 2020). A lesser prevalence of GI parasites was recorded in Maharashtra (28%) and Meghalaya (29%). However, the north-eastern regions or states are the primary focus of pig rearing in India due for the consumption practice of pig meat in their routine food habits as reported (Laha *et al*. 2014). The parasitic class-wise analysis revealed that the protozoa (30%) had the maximum occurrence, followed by nematodes (26%), trematodes (8%), and cestodes (4%). The prevalence of GI parasites was higher in the slaughterhouse samples (84%) compared to faecal samples (46%). The prevalence of GI

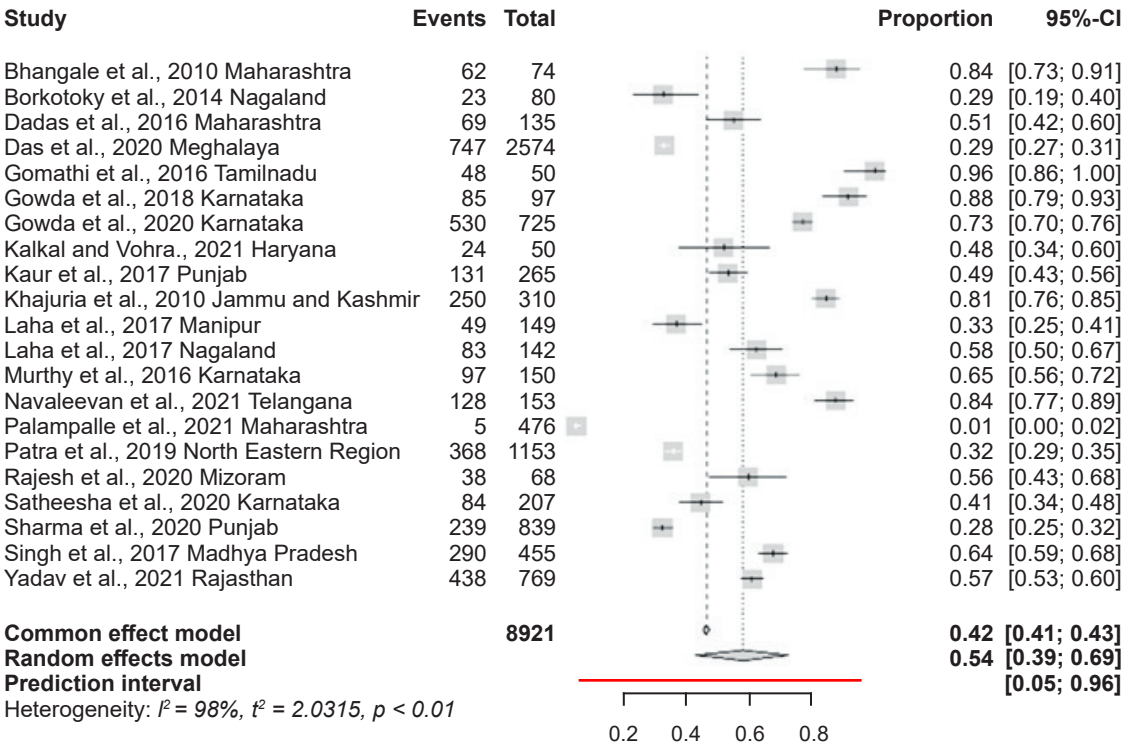

Fig. 2. Forest plot of GI parasites prevalence estimates in pigs of India.

parasitic species in pigs found higher in coccidia (29%) followed by *Ascaris* spp. (27%), *Balantidium coli* (22%), *Eimeria* spp. (20%), whereas lesser prevalence was found in *Globocephalus urosubulatus* (0.7%). The observations from the present study were in agreement with the study carried out in Mumbai region which found that the *Ascaris* spp. was the most prevalent parasite and least prevalent was *Globocephalus urosubulatus* (0.74%) (Dadas *et al*. 2016). In trematodes, the higher prevalence was observed in Amphistomes (12%), least in *Schistosoma* spp. (6%). The highest prevalence in Cestodes was observed for *Moniezia expansa* (4.2%). In nematodes, a higher prevalence found in *Ascaris spp*. (27%) and lowest in *Globocephalus urosubulatus* (0.7%). Previous study from Punjab state of India recorded that prevalence of *Strongyloides* spp. (4.5%) in pigs (Kaur *et al*. 2017) which is similar to the present

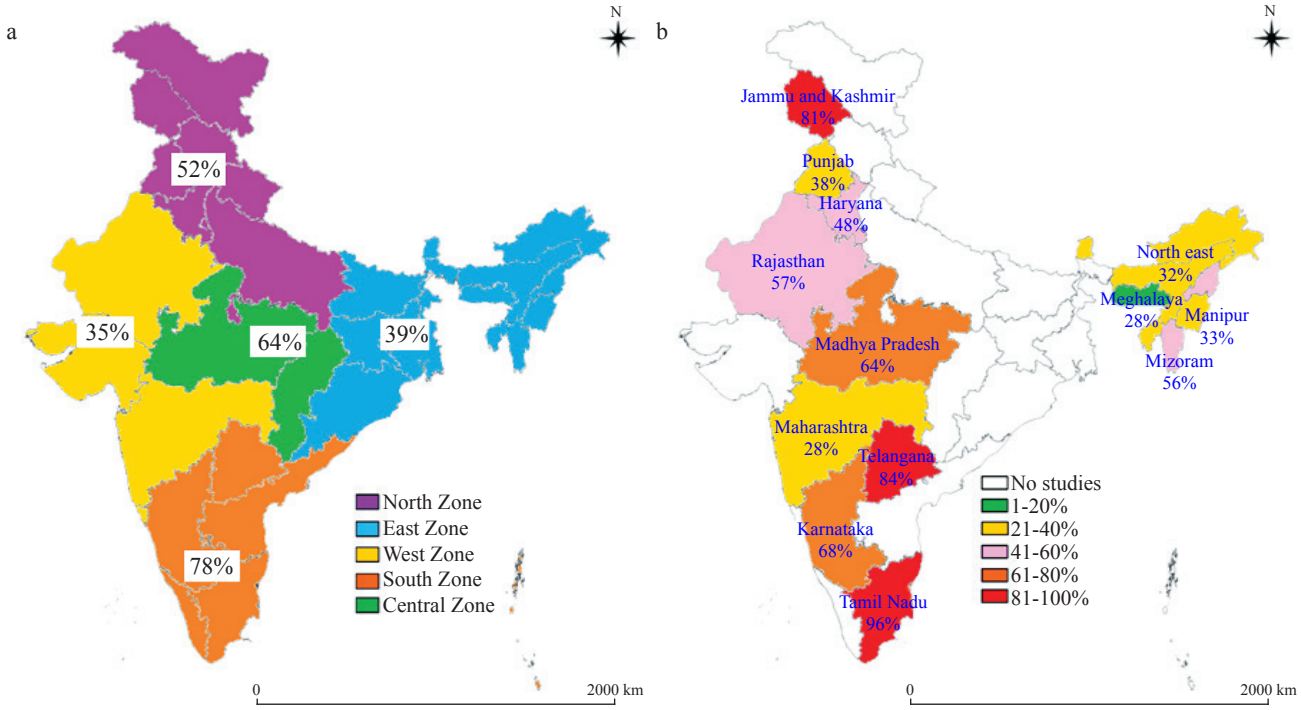

Fig. 3. Map showing (a) zone-wise and (b) state-wise GI parasites prevalence in pigs of India.

study with a prevalence of *Strongyloides* spp. (5%). The higher prevalence in protozoa was observed in coccidia (29%) and minimum in *Giardia* spp. (4%). In an earlier study from Meghalaya, Das *et al*. (2020) reported that the prevalence of protozoan parasites such as *Balantidium coli* (39.36%), *Eimeria* spp. (35.34%), *Cryptosporidium* spp. (10.04%), *Isospora* spp. (7.10%), *Entamoeba polecki* (5.62%) and *Giardia* spp. (2.54%) which concurred with the present study. Among parasite classes, the protozoa infection was found to be more predominant followed by the nematode infections in pigs. High prevalence rate of GI parasites may occur in rainy season has been reported and could be due to the suitable macro and microclimatic conditions, agro ecological factors favouring the growth, survival and dissemination of infective stages in the pasture, leading to higher infections in pigs (Singh *et al*. 2017). Most common GI parasites found in pigs are *Ascaris lumbricoides, Ascaris suum, Trichiuris trichiura, Trichiuris suis, Schistosoma suis, Fasciolopsis buski, Fasciola hepatica,* etc. out of which most are nematodes (Patra *et al*. 2019) and concurred with the present study.

The Cochran Q statistics represented a highly significant ($P<0.01$) difference between the studies based on year-wise, zone-wise, state-wise, host-wise, parasitic class wise, sample-wise and parasite species wise except for the year 2010, cestodes which showed no significant difference among the studies. This might be due to the lesser number of studies included for the meta-analysis. Based on the analysis of GI parasite species, the Cochran Q values revealed that the *Simondsia paradoxa* and *Metastrongylus* spp. in nematodes and *Cryptosporidium* spp. in protozoa also showed no significant difference. The poor management practices attributed to the high prevalence of GI parasites in pigs (Dadas *et al*. 2016). This could also be because of the fact that majority of pigs are reared by tribal people under backyard condition without proper information on scientific management practices such as housing and feeding of pigs (Borkotoky *et al*. 2014). The prevailing environmental conditions have a key impact on parasite populations, most significantly the free living form of the GI parasites. Further, the management practices including frequent removal of manure and litter from pig sheds, anthelminthic treatment during rainy and summer season and the use of disinfectants can be supportive in effective control of GI parasites of pigs (Sharma *et al*. 2020). Furthermore, there is need to deworm the pigs before the monsoon season to effectively prevent the infection of GI parasites in pigs (Laha *et al*. 2014). The epidemiology of GI parasites are influenced by the peculiar topography, rainfall, humidity and soil quantity available in a particular geographical locations as described (Borkotoky *et al*. 2014).

In conclusion, the higher possibility for the occurrence of GI parasites in various zones, states, parasite classes, sample type and parasites species have been identified in the present study. This will assist the policy makers and various stakeholders to make informed decision while utilizing the limited resources to be used effectively. Number of studies reporting the GI parasites prevalence in pigs are very limited and there is need for more number of studies. However, in the recent years, pig farming is gaining importance due to ample opportunities for economic benefits and more number of prevalence studies are forthcoming. This study forms the first report on overall estimates of GI parasites in pigs of India based on meta-analysis and also provides the baseline information and collection of prevalence studies on GI parasites of pigs at one place. Further, there is need for greater number of studies in pigs on the prevalence of GI parasites from other states in India. Based on this study, there is an urgent demand for the effective deworming of the pigs in a scheduled manner to overcome the infection of GI parasites. This will help in improving the quality of pork and meat products from pigs for consumption and also for the trade purposes. The necessary measures undertaken to prevent the GI parasites occurrence will improve the export trade for pig meat and meat products in the global market and also upgrade the financial profits from the piggery farming in India.

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